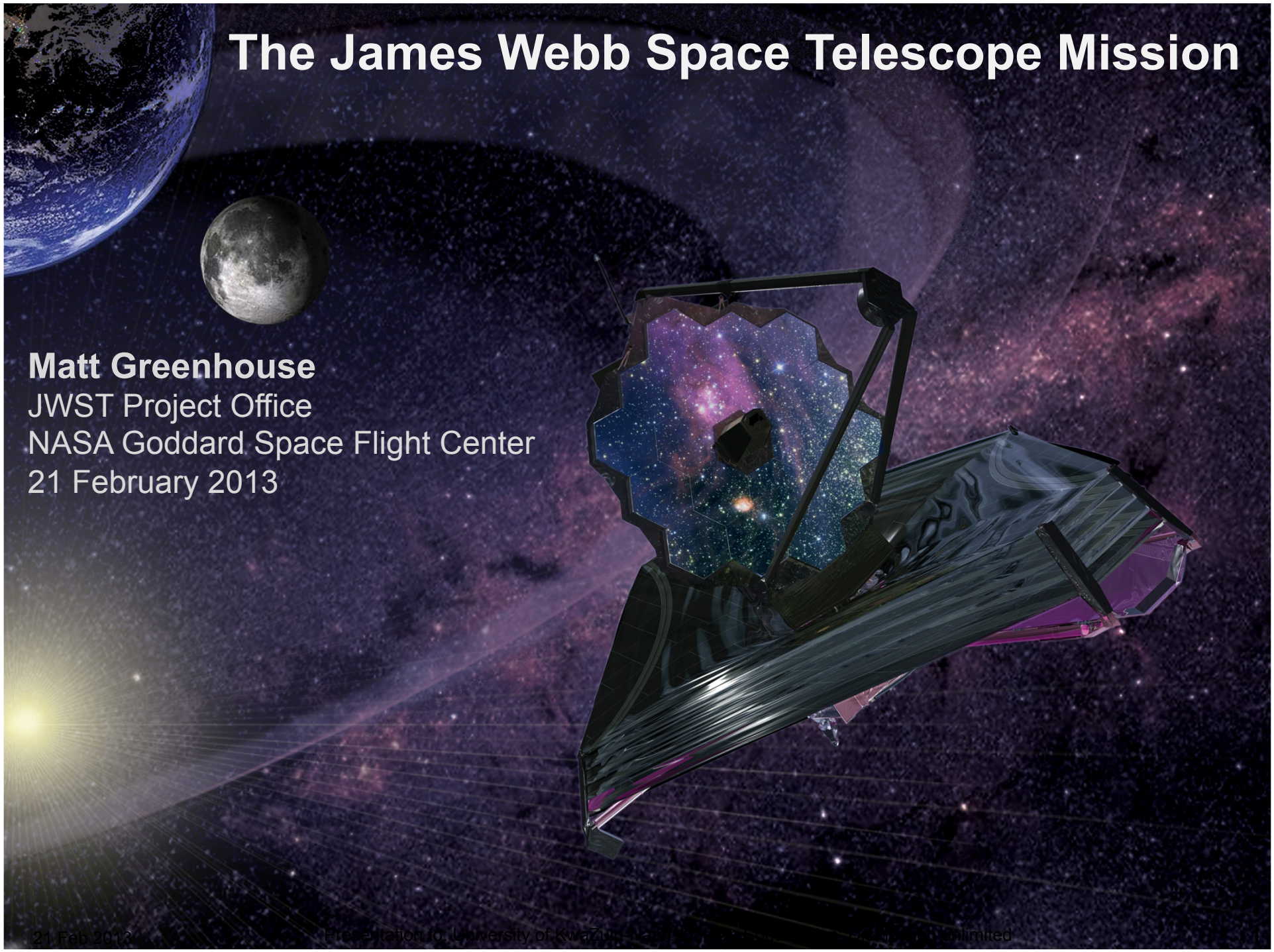


The James Webb Space Telescope Mission



Matt Greenhouse

JWST Project Office

NASA Goddard Space Flight Center

21 February 2013

JWST is a general astrophysics mission for use by the international astronomical community

- Often described as the successor to the Hubble Space Telescope, the JWST will serve astronomers world-wide in much the same way:
 - Science & mission operations managed by the Space Telescope Science Institute
- The science investigations performed by the JWST will be determined by the General Observer community.
 - Observing time allocated through annual peer-reviewed proposal cycles
- Four science themes have been defined by a succession of international community working groups to guide engineering development of the JWST:

Identify the first bright objects that formed in the early Universe, and follow the ionization history.

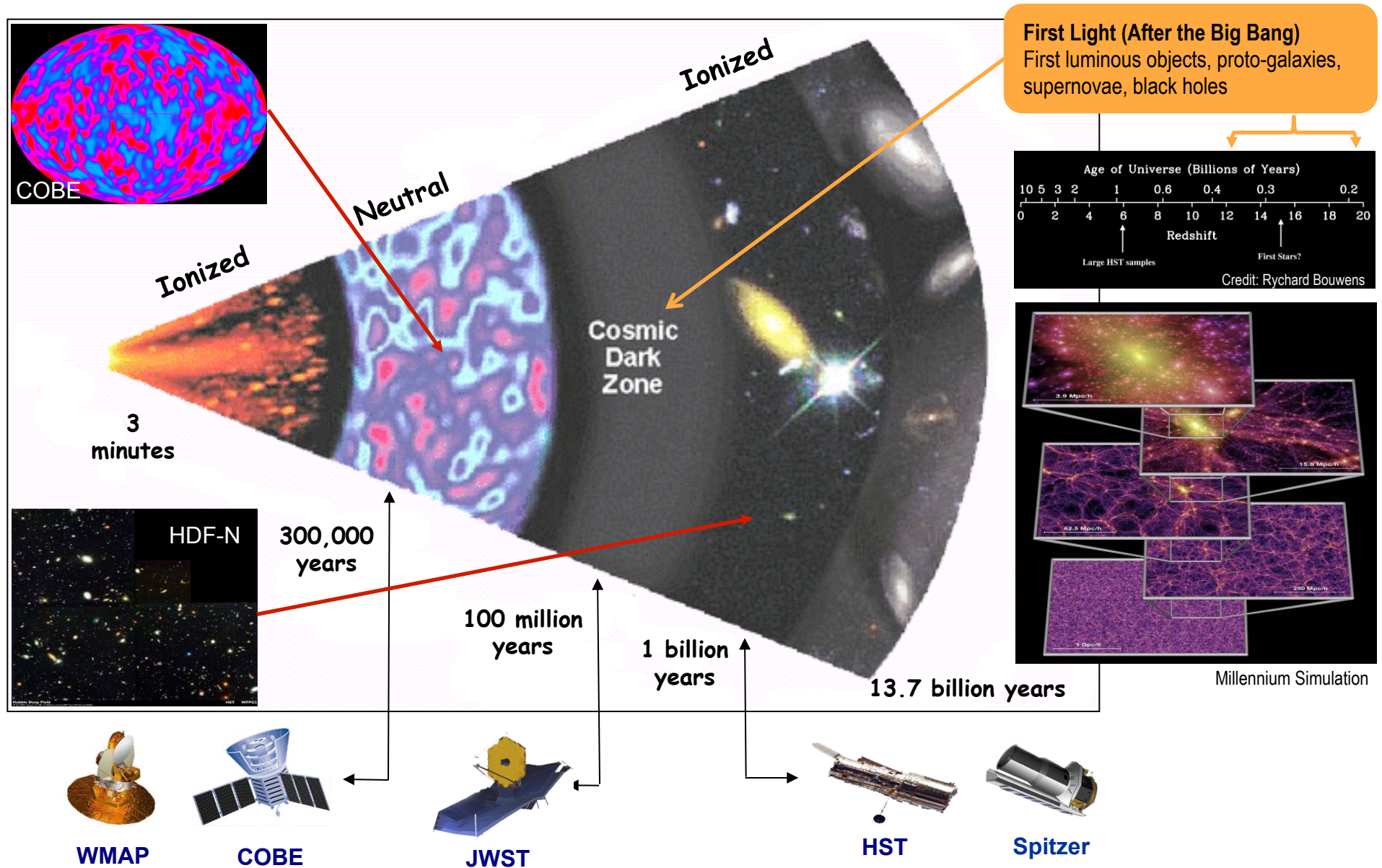
Determine how galaxies, their morphology, and active nuclei evolved to the present day.

Observe the birth and early development of stars and the formation of planets.

Study the physical and chemical properties of solar systems (including our own) and where the building blocks of life may be present.

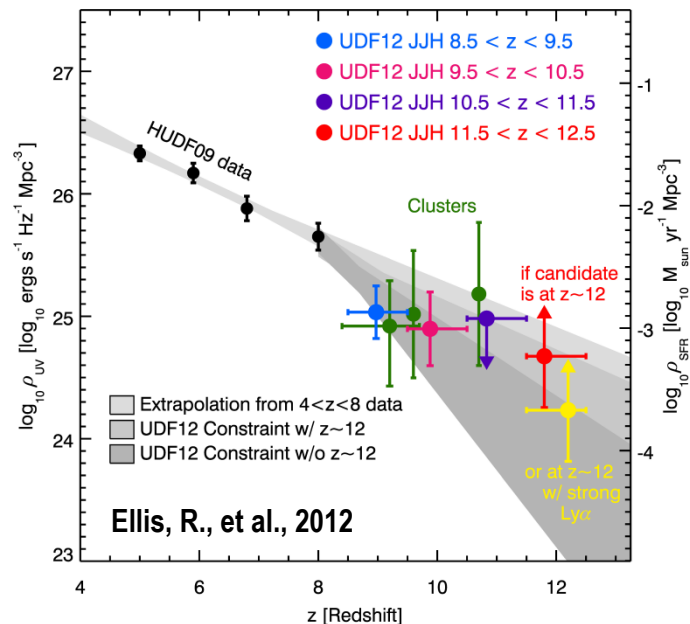
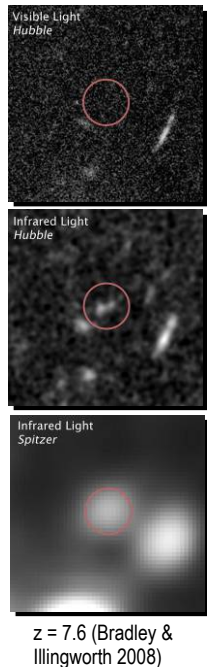
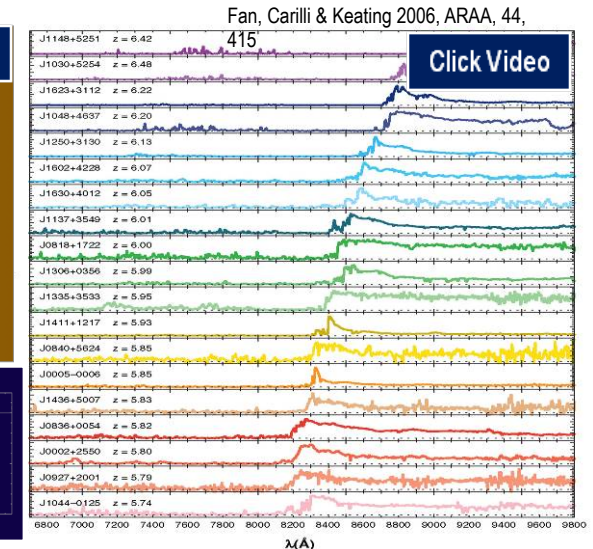
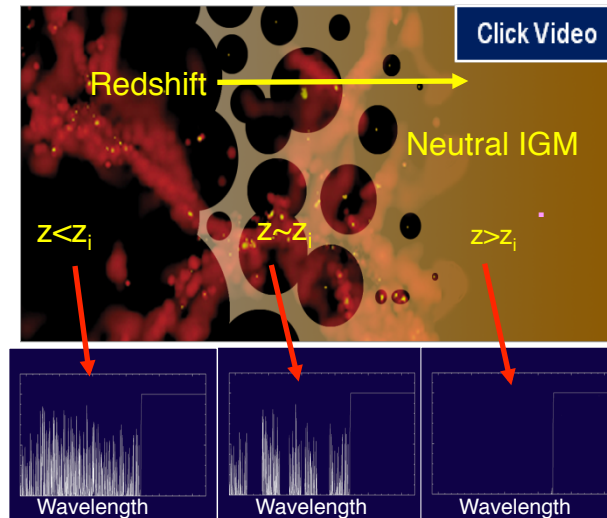


JWST is designed to observe formation of the first galaxies



Key questions about the galaxy formation era:

- How did black holes form and interact with their host galaxies?
- What is the nature of the first galaxies?
- When did re-ionization of the inter-galactic medium occur?
- What caused the re-ionization?

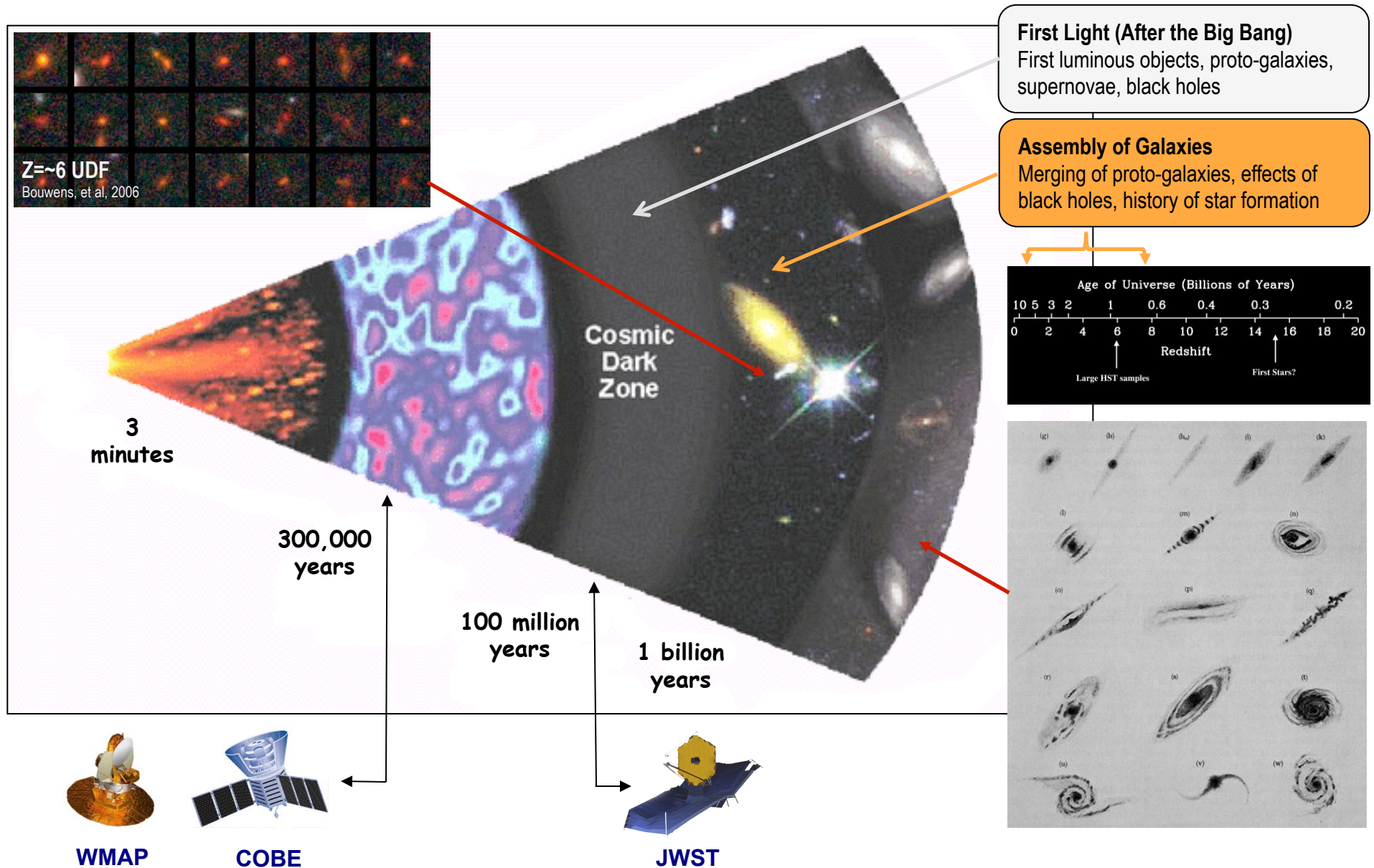


Key Enabling Design Requirements:

- Deep near-infrared imaging survey (1nJy)
- Near-IR multi-object spectroscopy
- Mid-IR photometry and spectroscopy

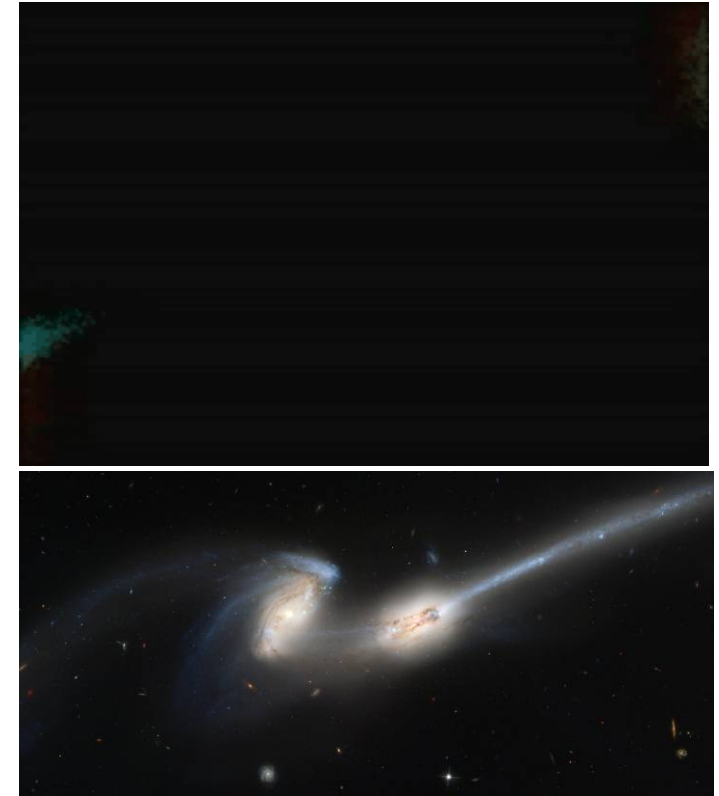
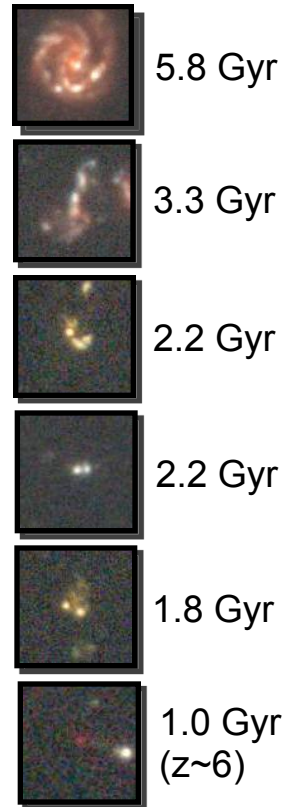
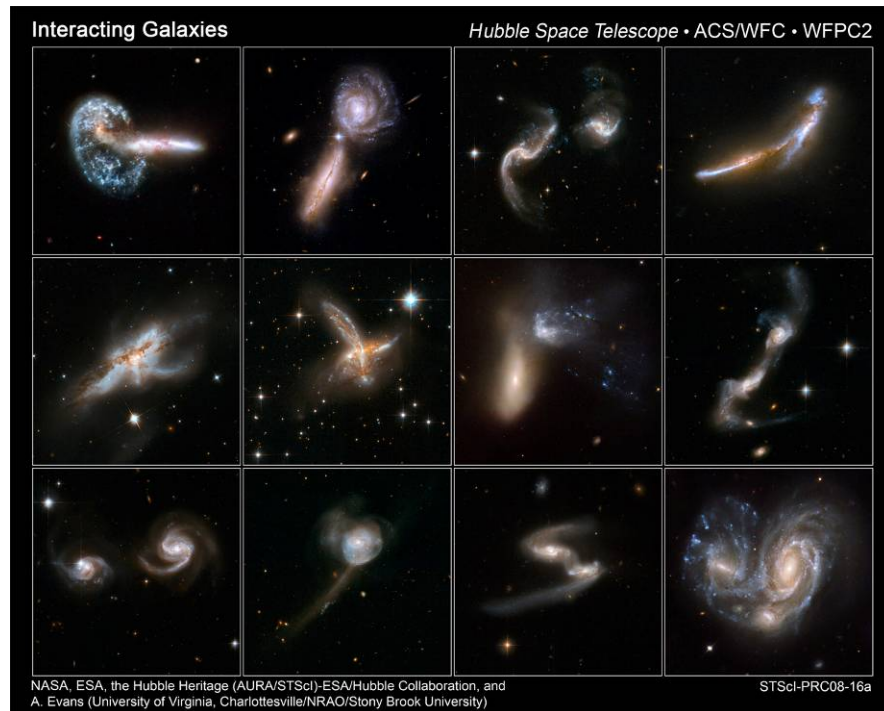
Redshift z	m_{AB}	F_v (nJy)	Lyman Break wavelength
0			0.12 μm
10	30.3	2.8	1.34 μm
15	30.9	1.6	1.95 μm
20	31.3	1.1	2.55 μm

JWST is designed to observe the evolution of galaxies



Key questions about galaxy evolution:

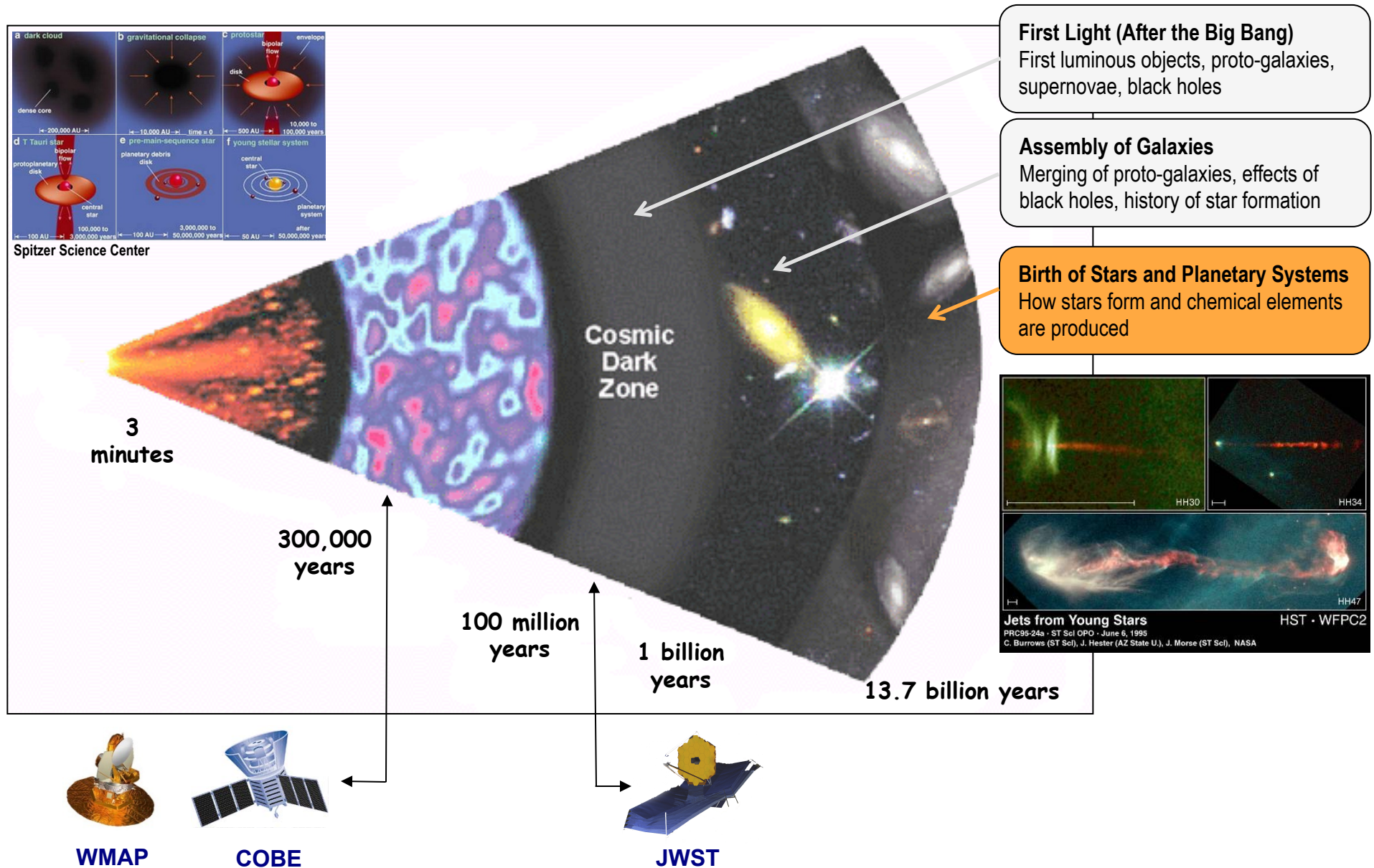
- When did the Hubble Sequence form?
- What role did galaxy collisions play in their evolution?
- How is the chemical evolution of the universe related to galaxy evolution?
- What powers emission from galaxy nuclei?



Key Enabling Design Requirements:

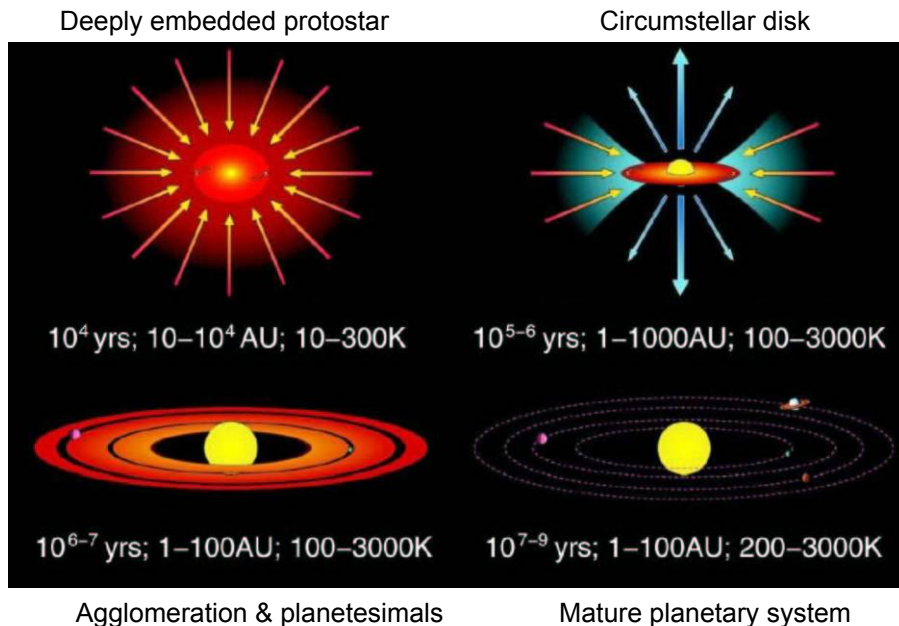
- Wide-area near-infrared imaging survey
- Low and medium resolution spectra of 1000s of galaxies at high redshift
- Targeted observations of galactic nuclei

JWST will observe how stars form in our galaxy



Key questions about star formation:

- How do molecular clouds collapse?
- How does environment affect star-formation?
 - Vice-versa?
- What is the mass distribution of low-mass stars?
- What do debris disks reveal about the evolution of terrestrial planets?



Credit: McCaughrean

Credit: McCaughrean & Andersen

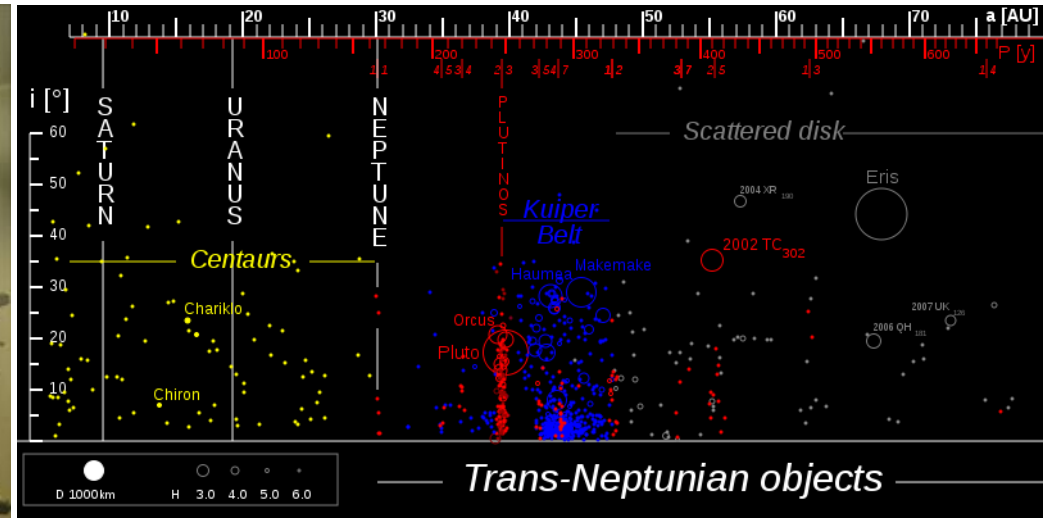


The Eagle Nebula as seen in the near-infrared

Key Enabling Design Requirements:

- High angular resolution near- and mid-IR imagery
- High angular resolution imaging spectroscopy

JWST will observe how planetary systems form and evolve



First Light (After the Big Bang)

First luminous objects, proto-galaxies, supernovae, black holes

Assembly of Galaxies

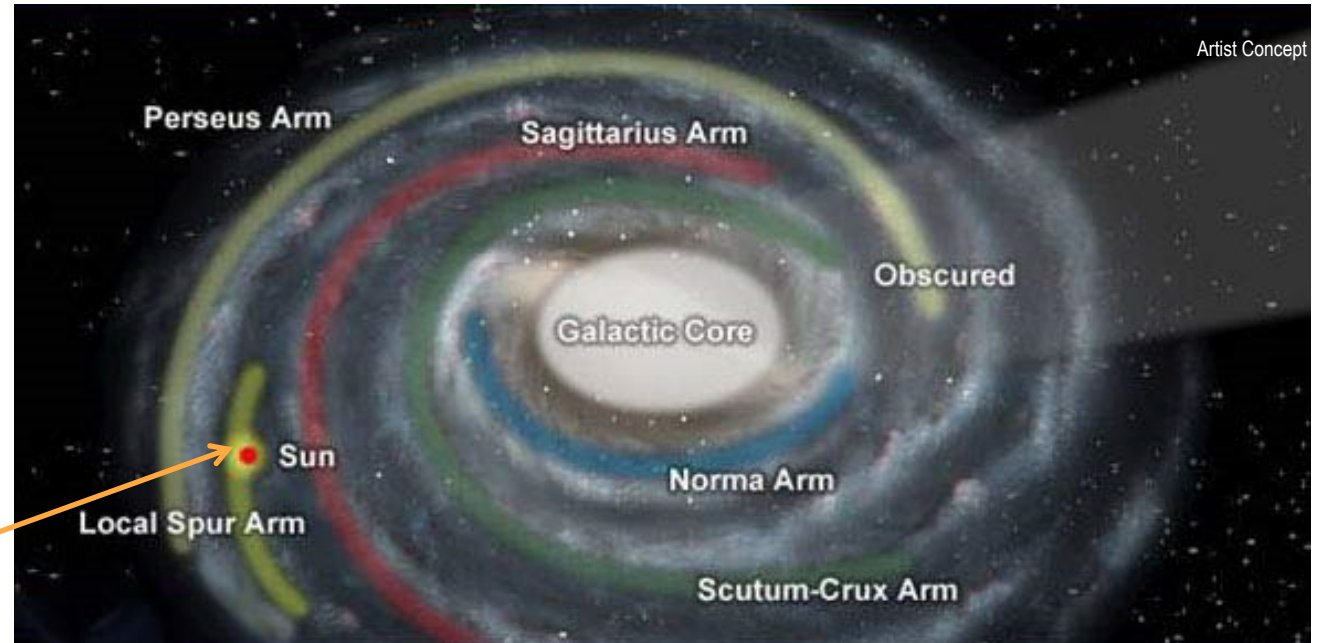
Merging of proto-galaxies, effects of black holes, history of star formation

Birth of Stars and Planetary Systems

How stars form and chemical elements are produced

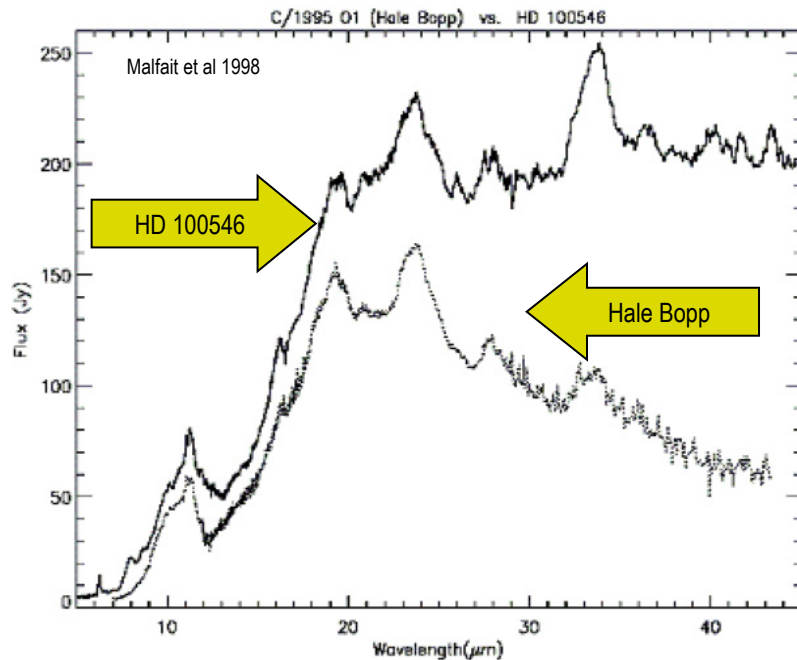
Planetary Systems & Origins of Life

Formation of planets



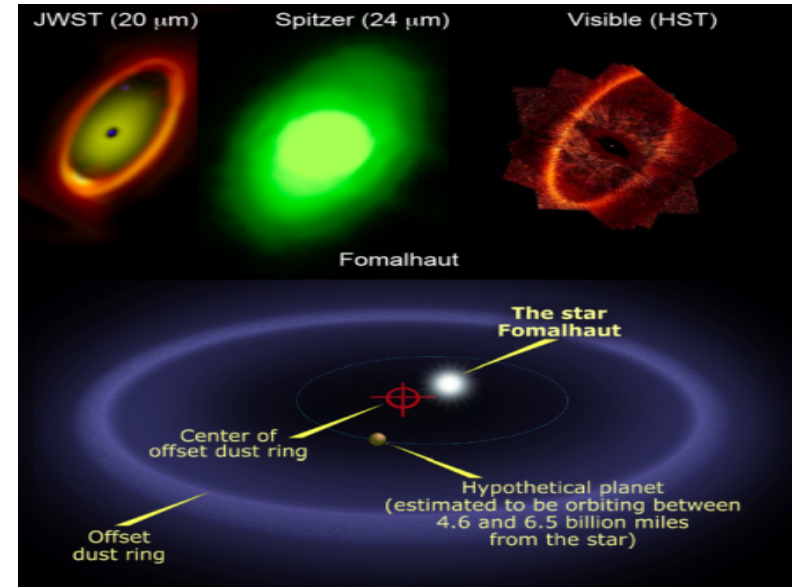
Key questions about planet formation:

- How do planets form?
- How are circumstellar disks like our Solar System?
- How are habitable zones established?

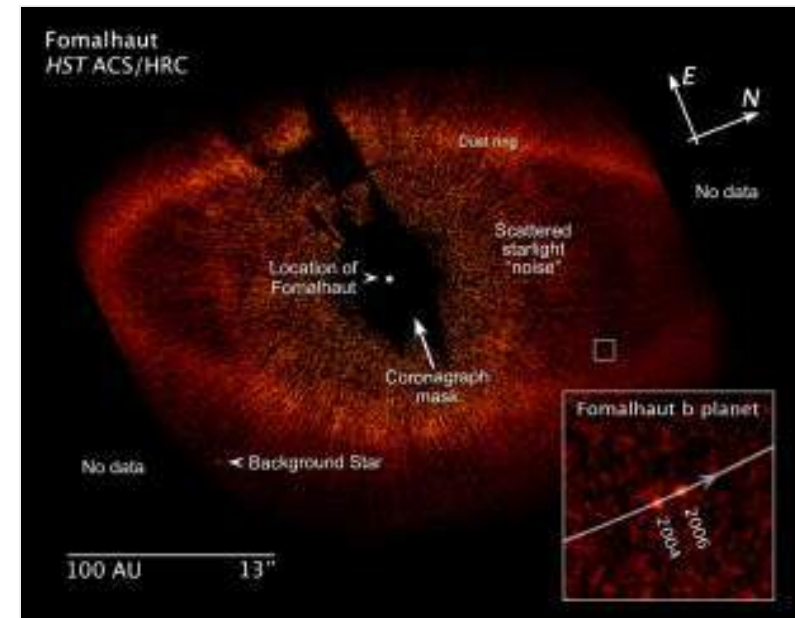


Key Enabling Design Requirements:

- Near- and mid-IR coronagraphic imagery
- Near- and mid-IR spectroscopy
- High cadence sub-array imagery & spectroscopy

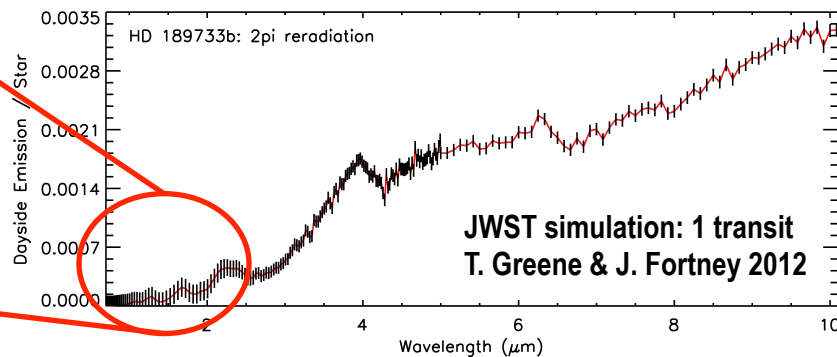
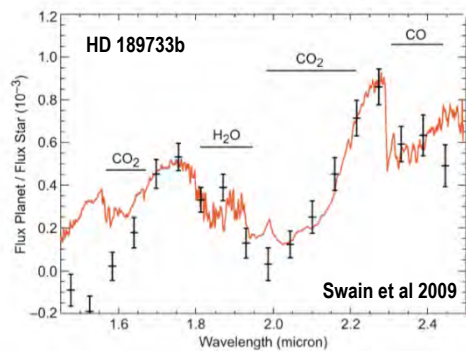
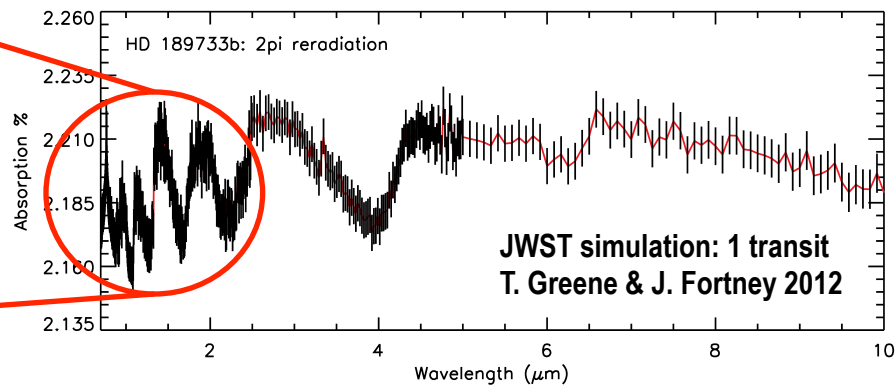
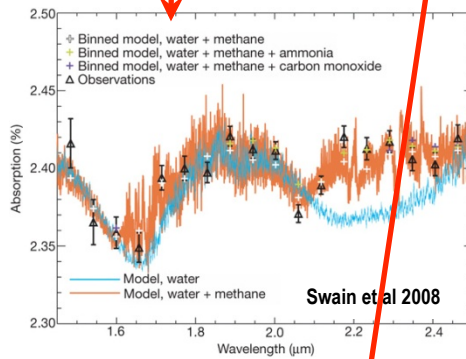
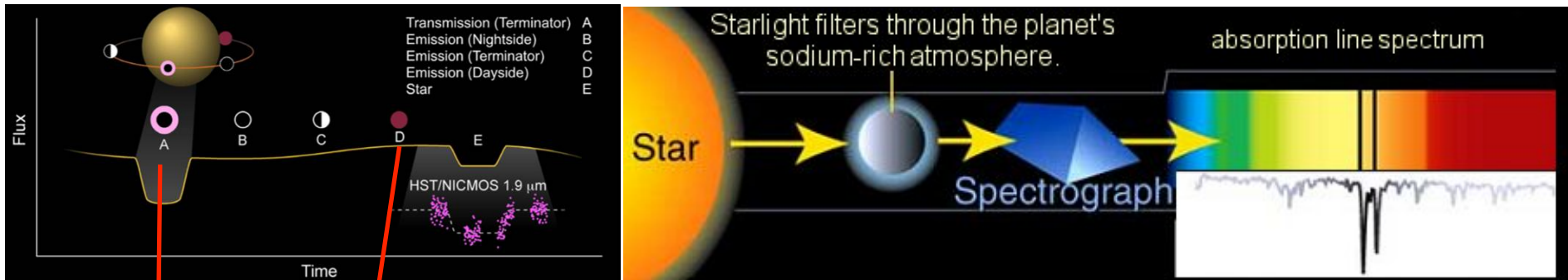


Kalas, Graham & Clampin 2005



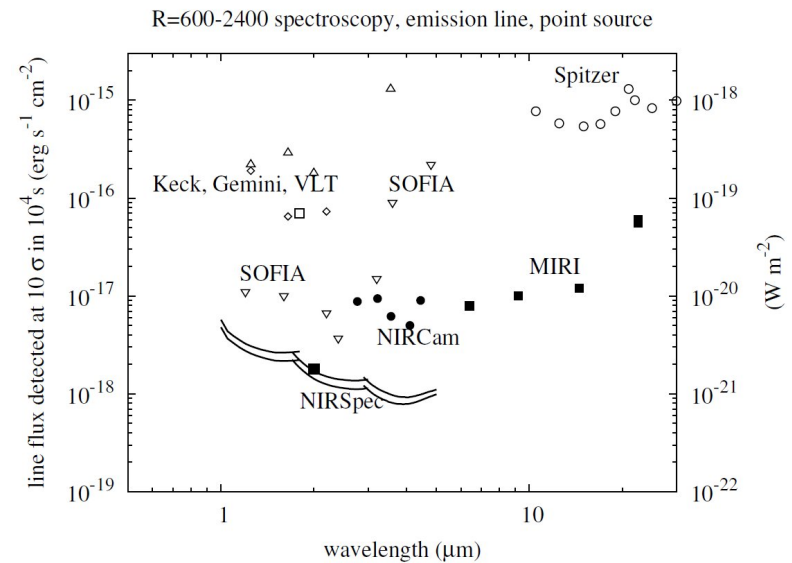
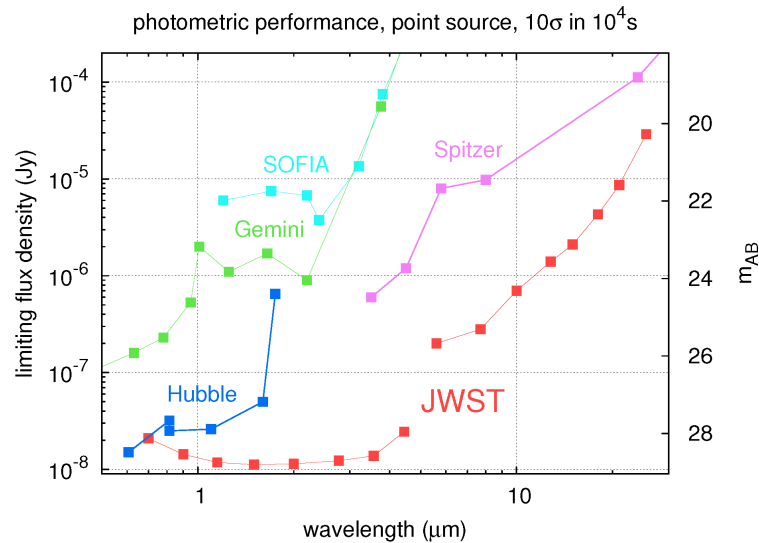
Kalas et al 2008

JWST will characterize exoplanet atmospheres

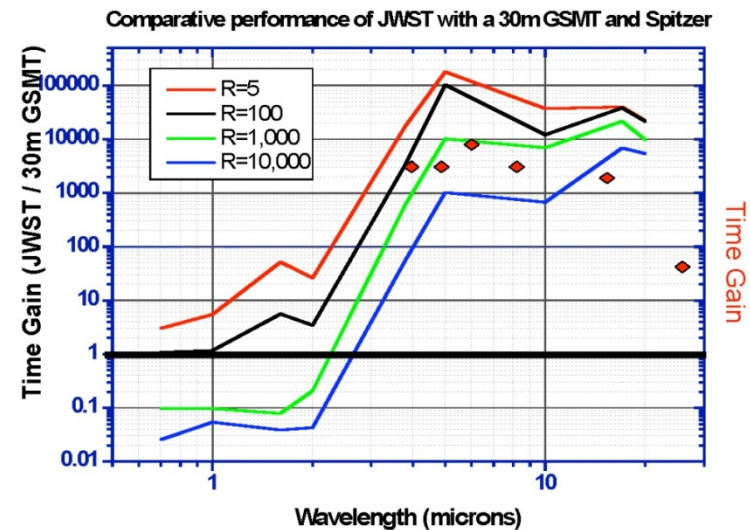
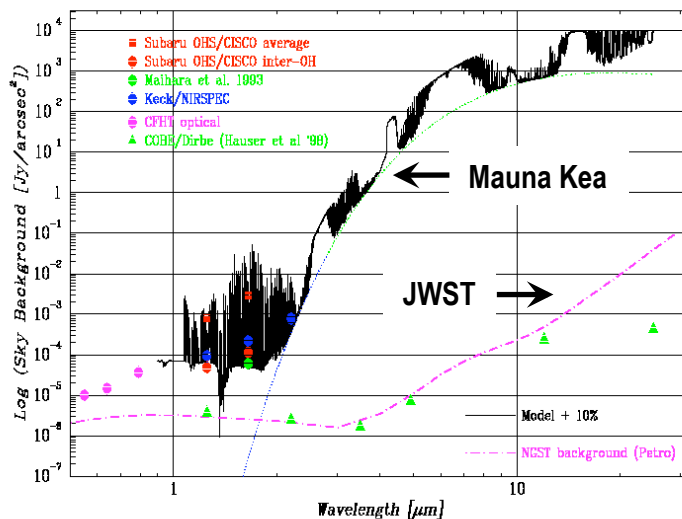


JWST can measure transit spectra over the 0.7 – 28 micron spectrum at resolutions ranging from ~100 to ~2000

JWST will achieve unprecedented sensitivity over the 0.6 – 29 micron spectrum



30 m ground-based facilities can exceed JWST performance for $R > 1000$ spectroscopy at wavelengths < 1.7 microns



JWST requires the largest cryogenic telescope ever constructed

To observe the early universe, the JWST mission requires:

7X the light gathering capability of the Hubble Space Telescope

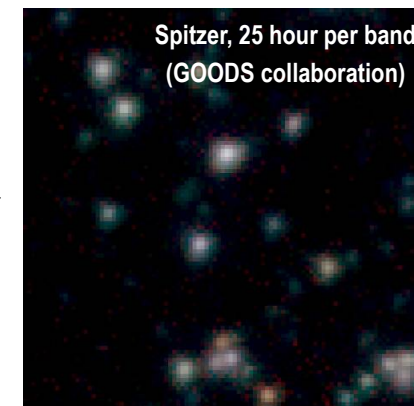
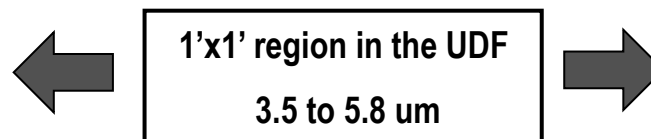
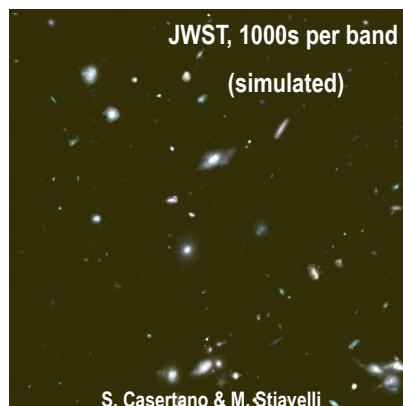
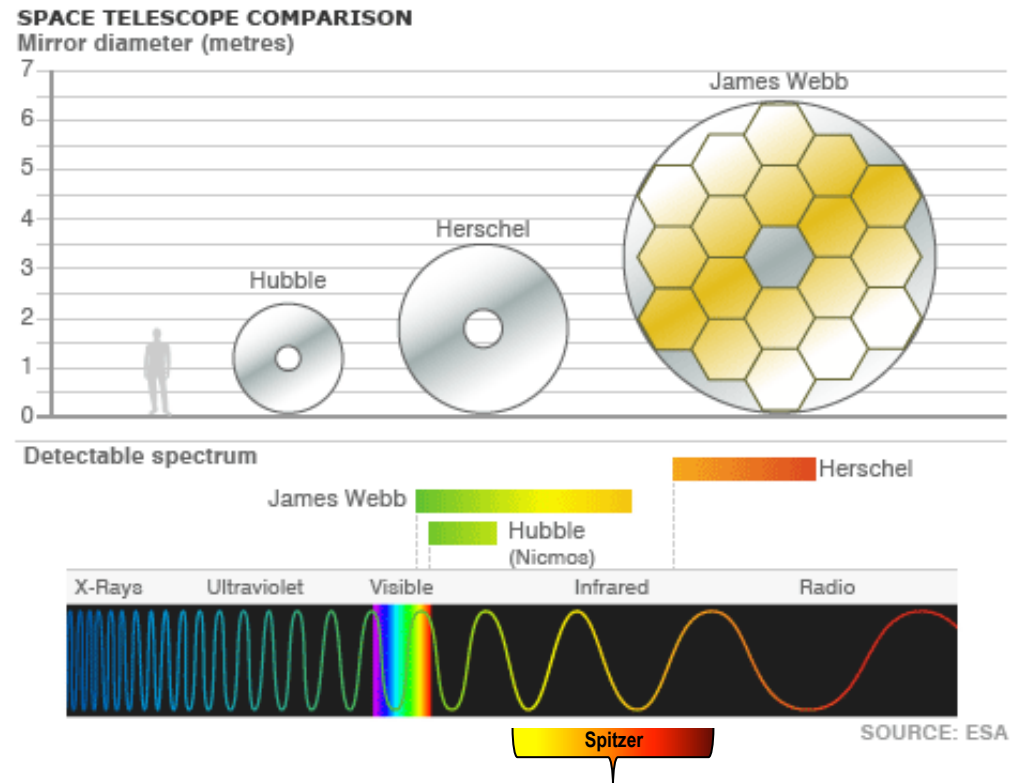
similar angular resolution in the near-infrared spectrum

wavelength coverage spanning the optical to mid-infrared spectrum

As a consequence, the observatory requires:

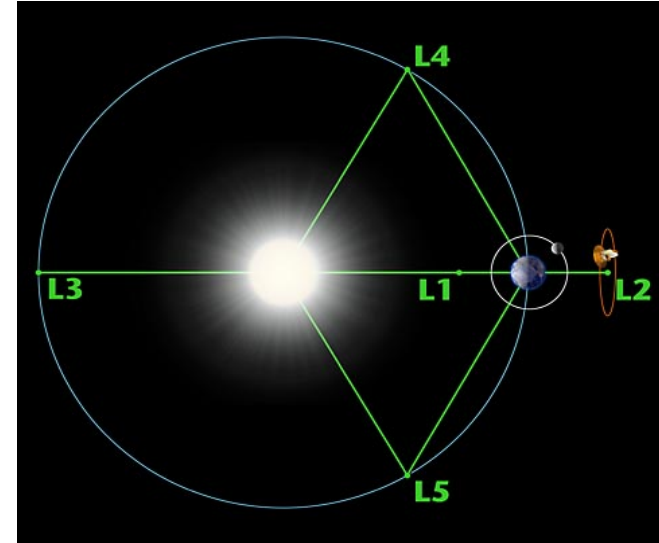
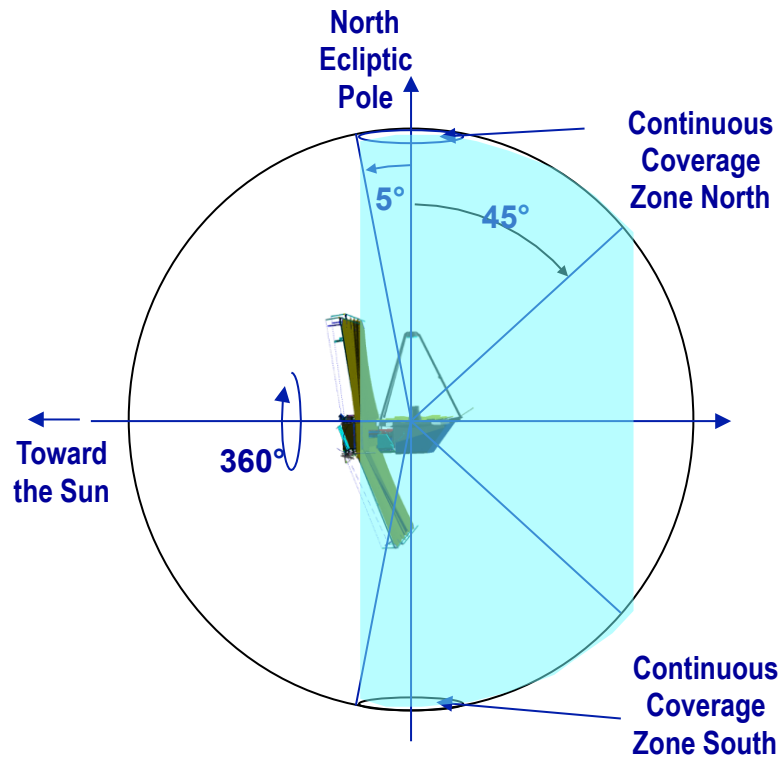
a primary mirror that is larger in diameter than available rocket fairings

a high stability 40-50K cryogenic operating temperature



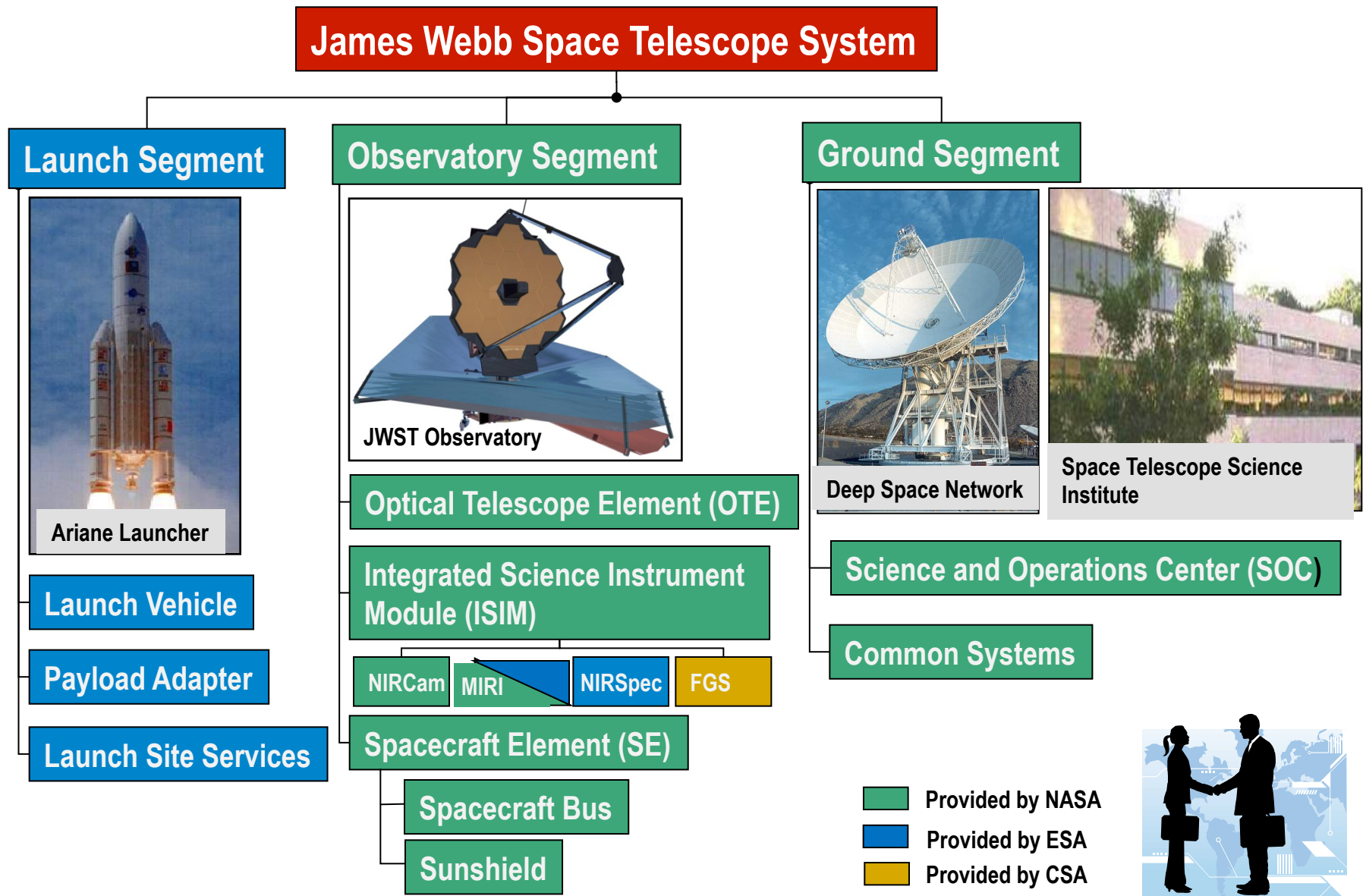
The JWST will be placed in orbit about the Sun-Earth L2 point approximately 1.5 million km from Earth

- An L2 point orbit was selected for JWST to enable passive cryogenic cooling
 - Station keeping thrusters are required to maintain this orbit
 - Propellant sized for 11 years ($\Delta v \sim 93$ m/s)
 - ~100 day direct transfer trajectory



- The JWST can observe the whole sky while remaining continuously in the shadow of its sunshield
 - Field of Regard is an annulus covering 35% of the sky
 - The whole sky is covered each year with small continuous viewing zones at the Ecliptic poles

The JWST program is a multi-agency partnership



The JWST space vehicle consists of three elements

Optical Telescope Element (OTE)

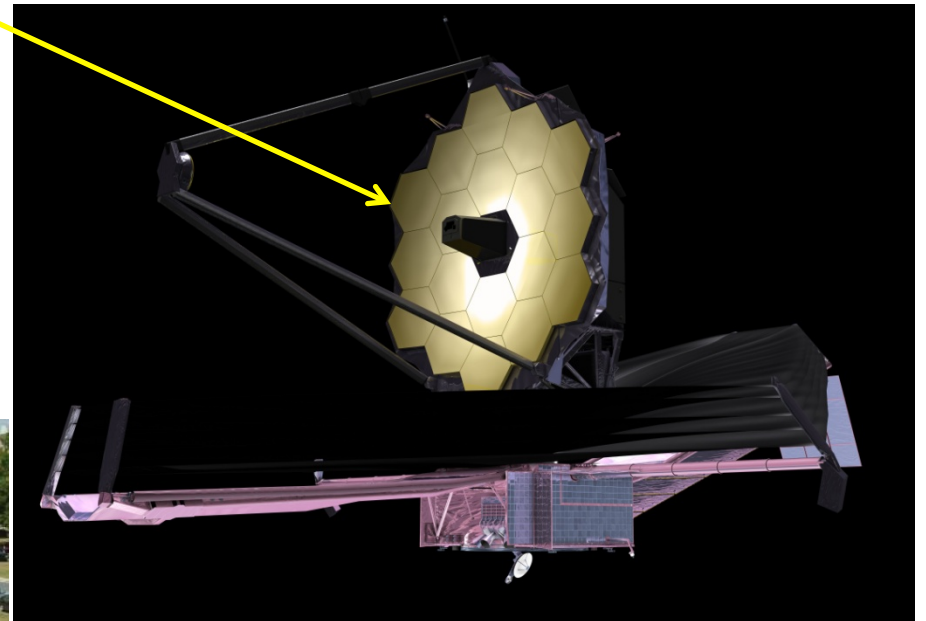
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

Spacecraft

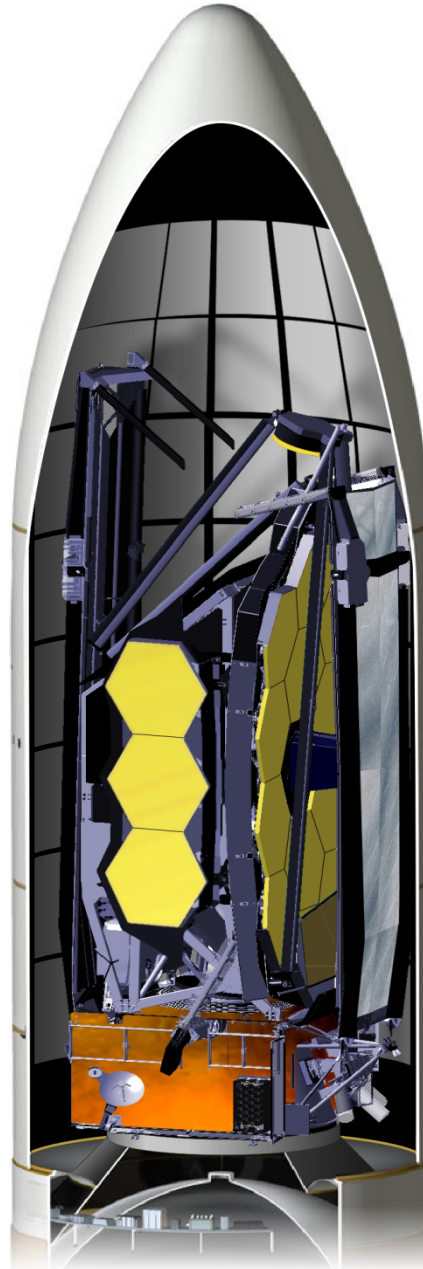
Attitude control, telecom, power & other systems



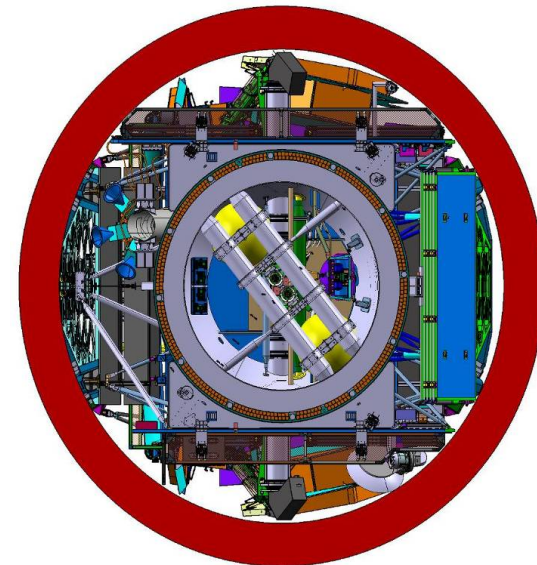
JWST requires a segmented deployable primary mirror



Ariane 5 ECA



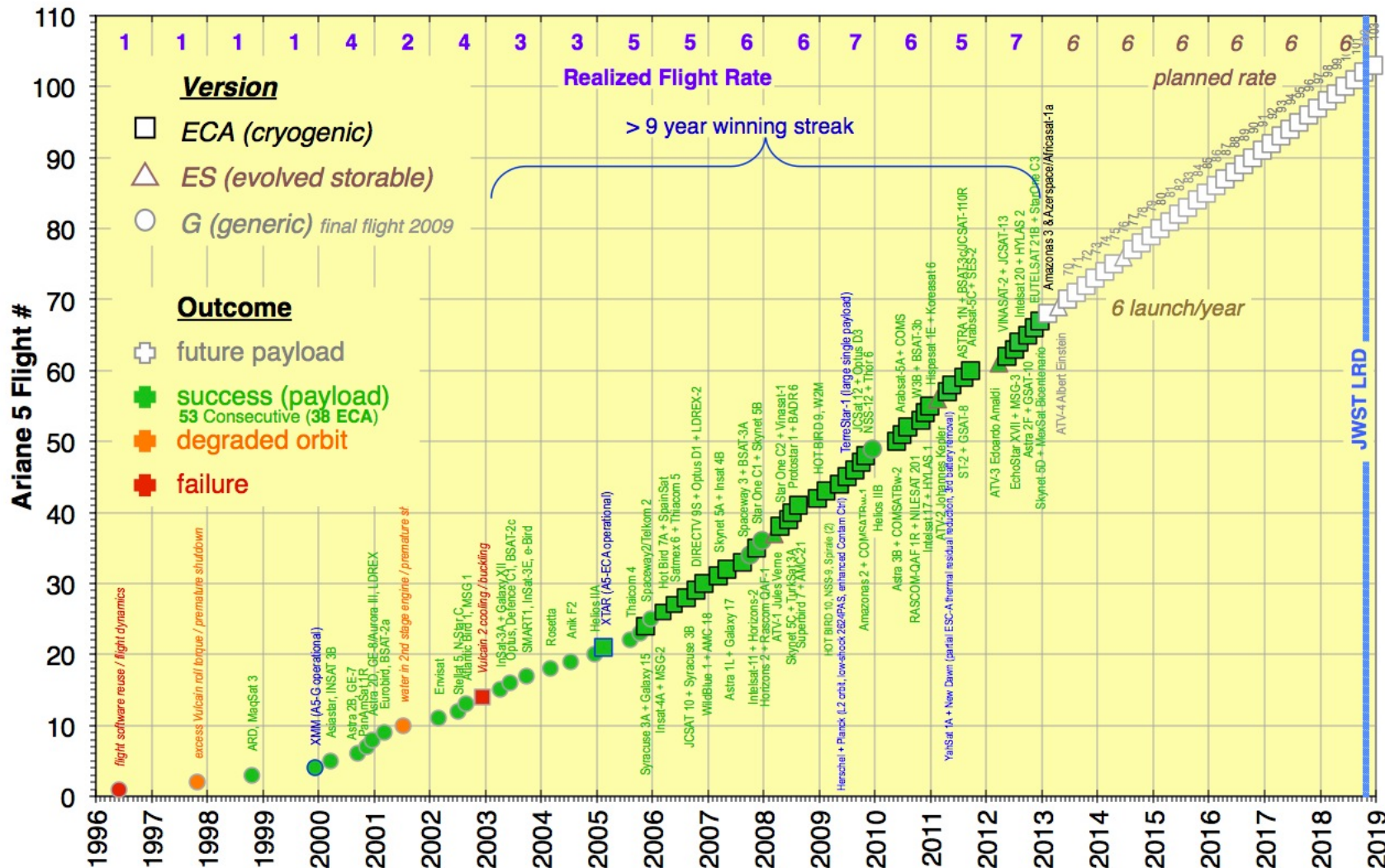
- JWST is designed to integrate with an Ariane V launch vehicle and 5 m diameter fairing
- Launch from Kourou Launch Center (French Guiana) with direct transfer to L2 point.
- Payload launched at ambient temperature with on orbit cooling to 50 K via passive thermal radiators
- JWST payload: 6330 kg



The Ariane 5 ECA has over 30 consecutive successes

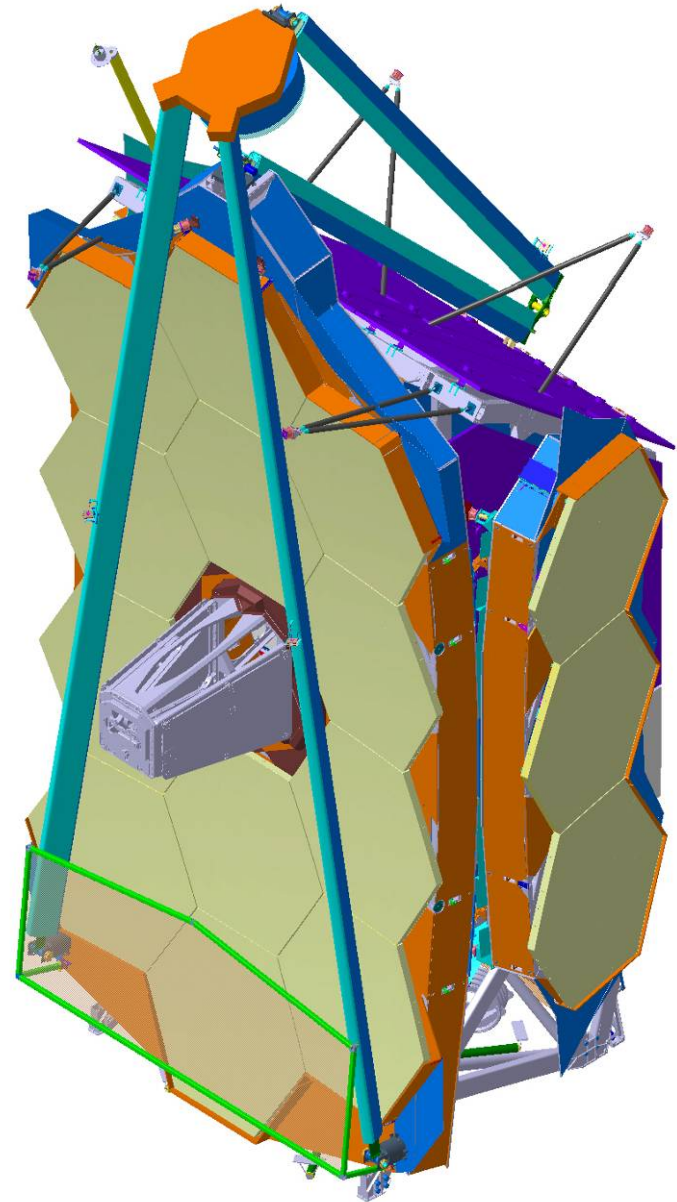
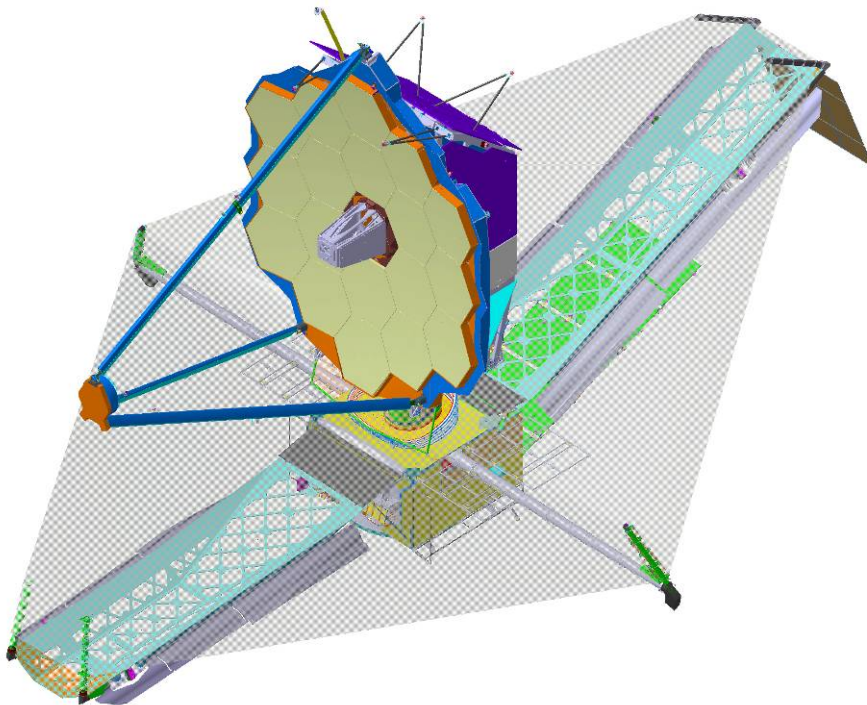
Status as of Feb 2013

6 flights planned for 2013

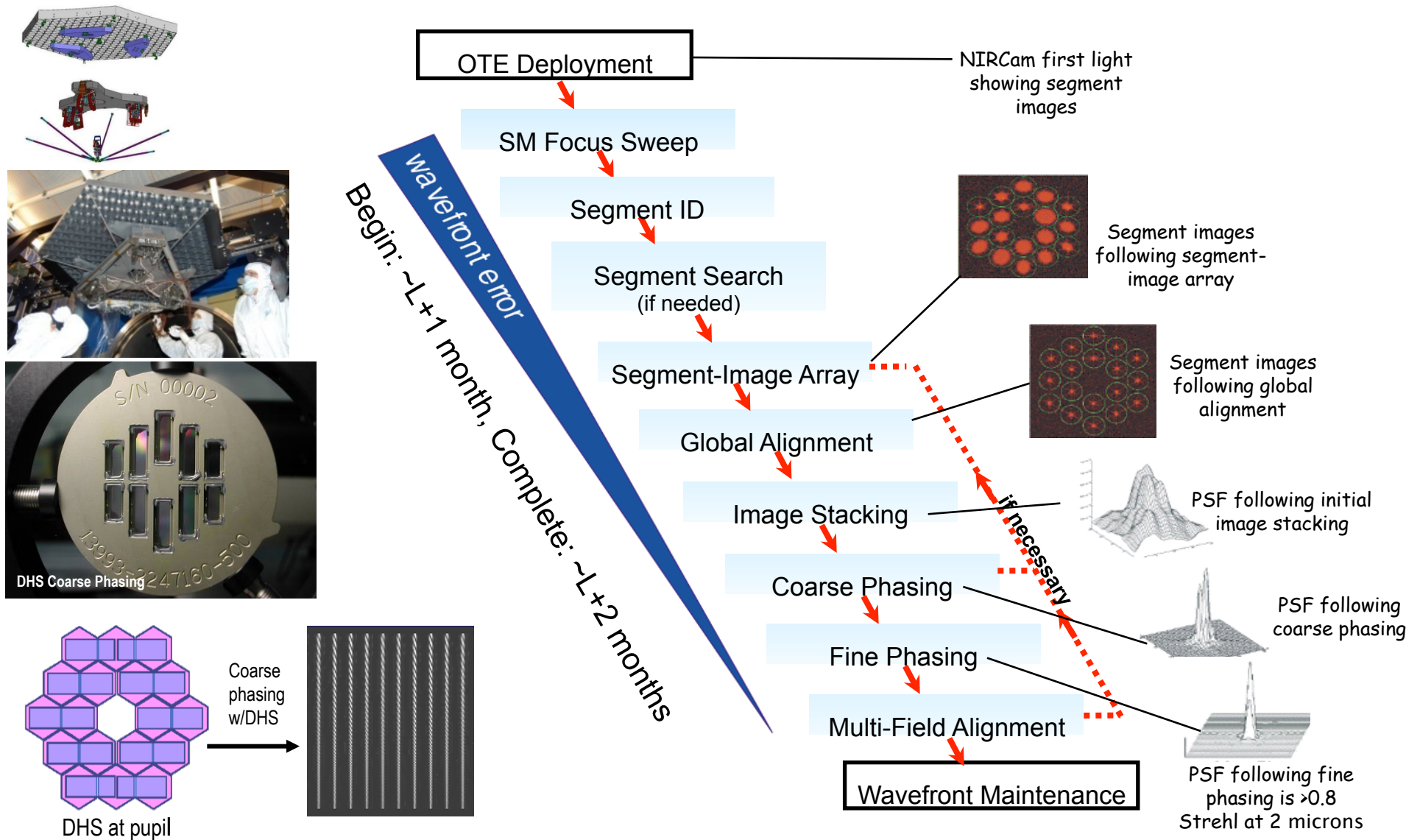


Deployment Sequence Overview

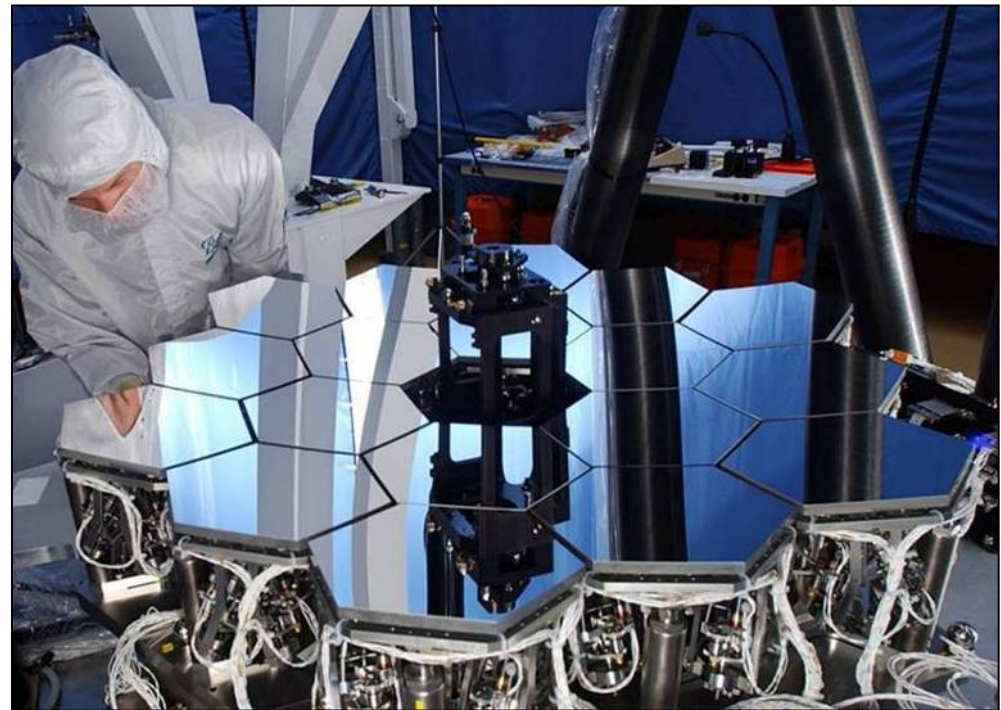
[Click Video](#)



The mirror segment mounts are mechanized, and a wavefront control system will be used to adjust each segment during flight, thus enabling them to perform together as a single large mirror.



The telescope wave front sensing and control procedure has been validated on a 1/6th scale fully functional engineering model



- Primary use is in validation of Flight Algorithms and software
- Also used to test JSC I&T process
- WFSC Testbed Telescope is a 1/6th scale, fully functional model of the JWST telescope with performance traceable to JWST (TMA, 18 7-dof segments, etc.).
- Used to perform TRL-6 end to end testing.
- Supports Multi-Field Measurements

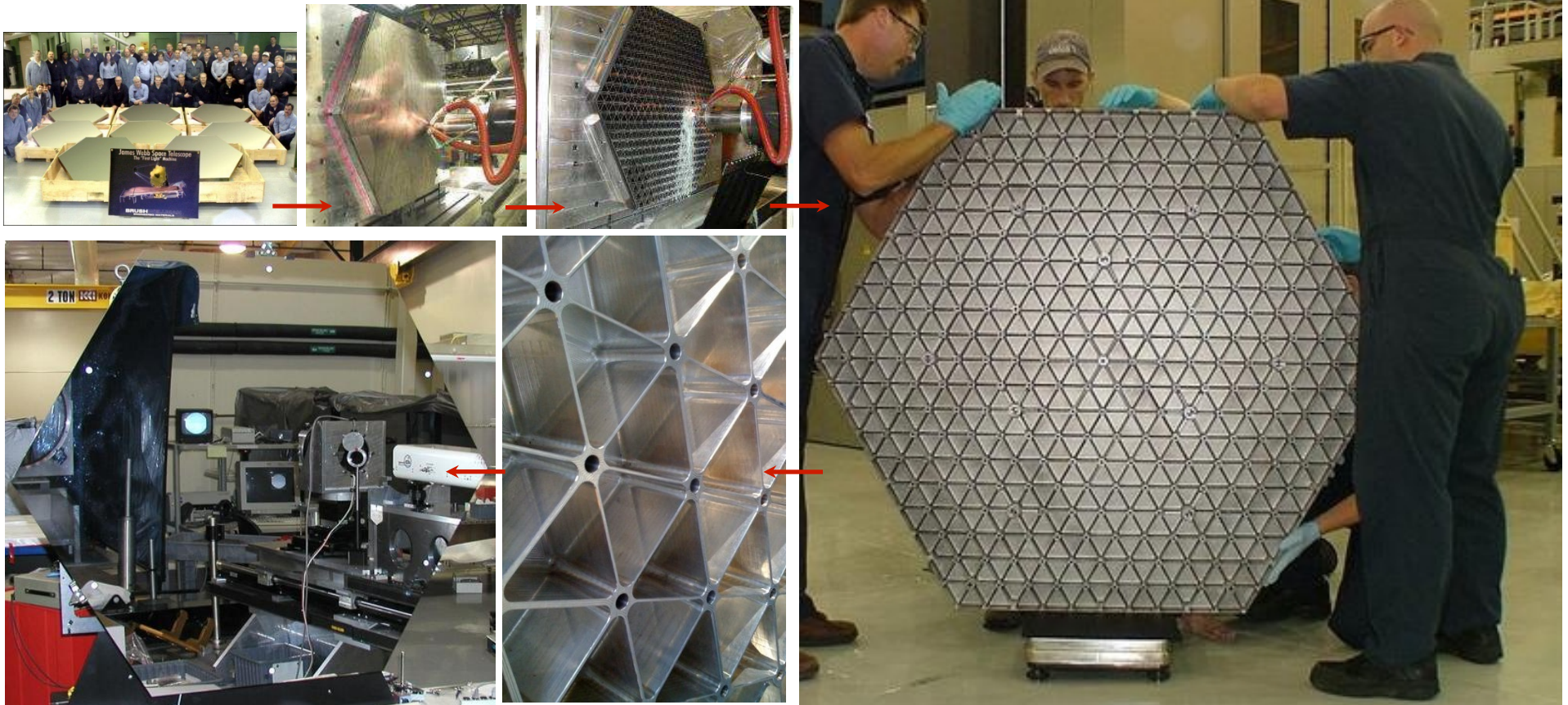
The telescope mirrors are fabricated from Beryllium

Key physical properties of Beryllium:

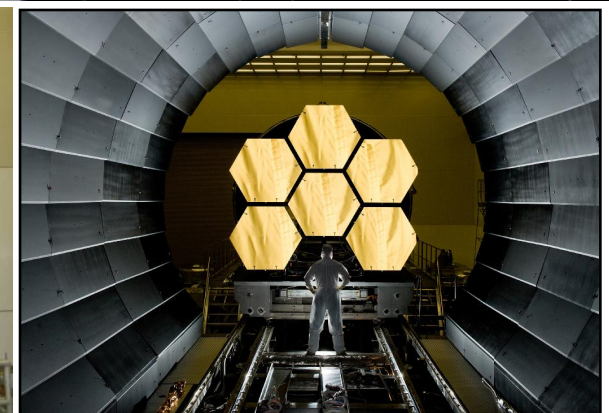
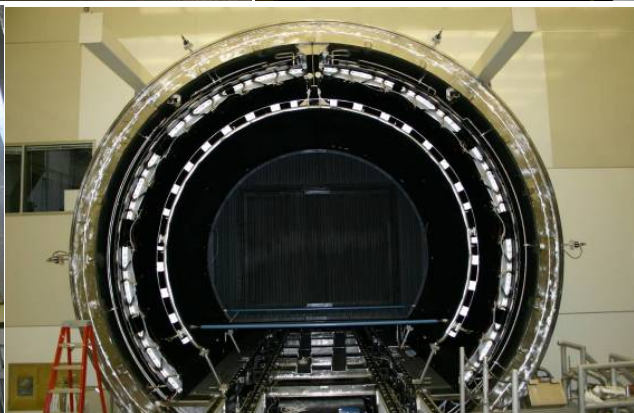
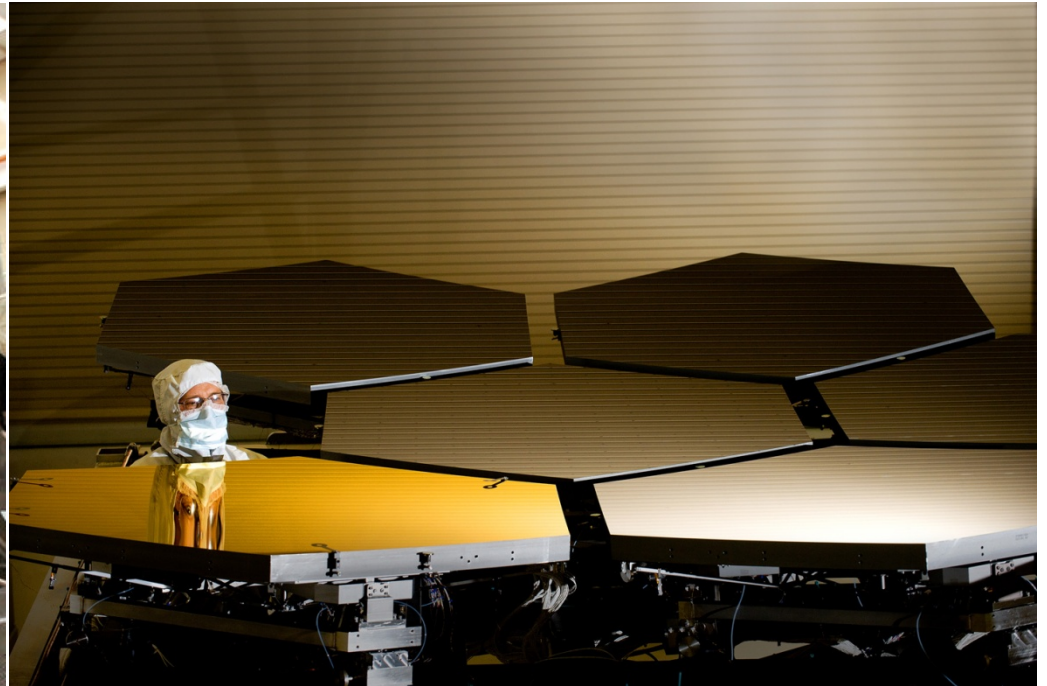
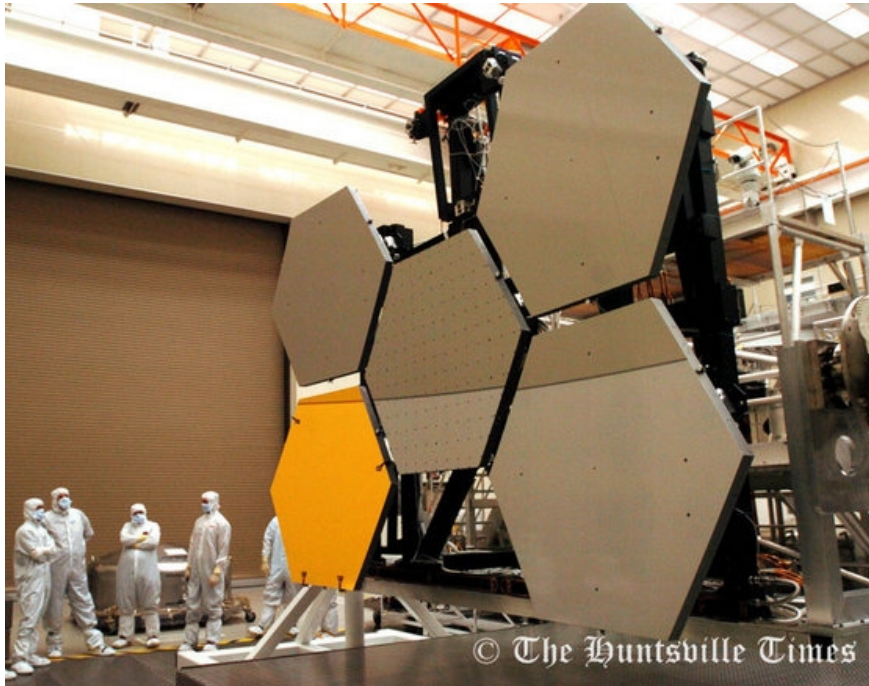
- low coefficient of thermal expansion at 50 K
- high thermal conductivity
- high stiffness to mass ratio
- Type O-30 spherical powder
- uniform CTE, high packing density, low oxide content

Primary mirror mass properties

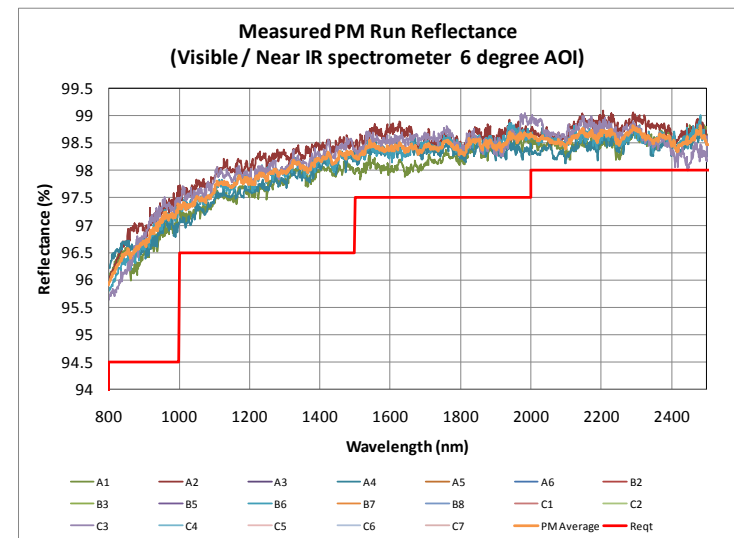
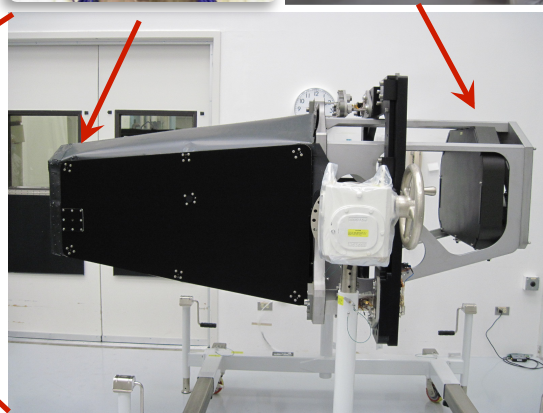
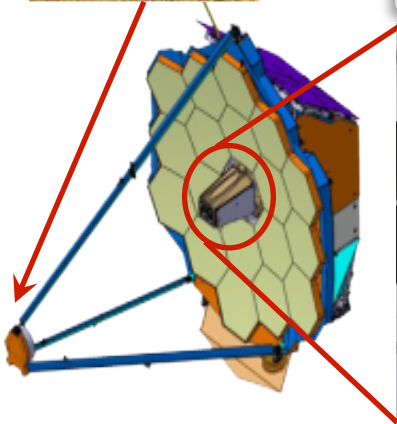
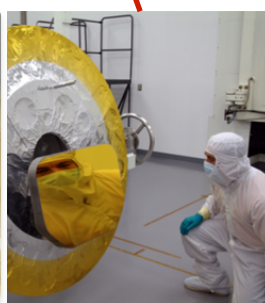
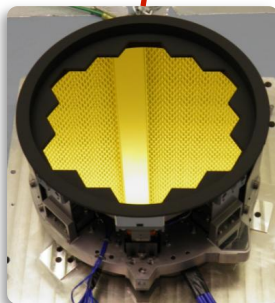
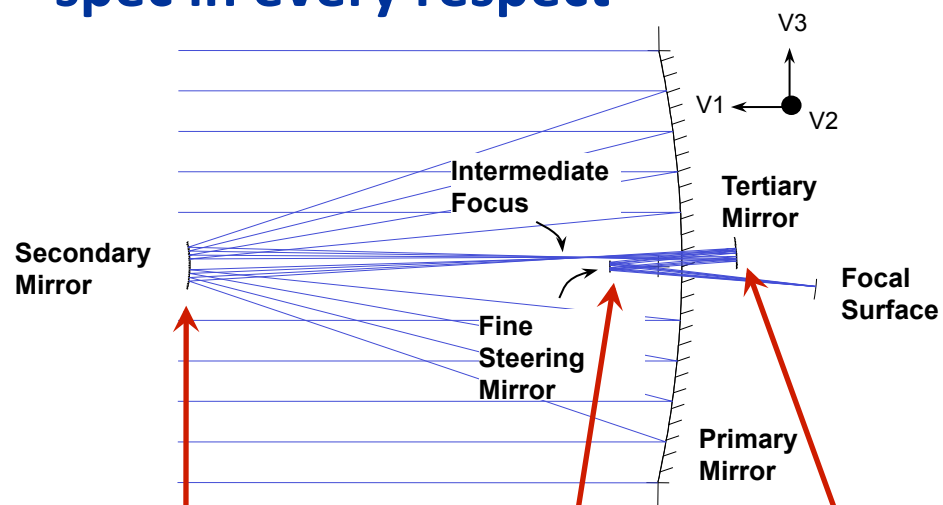
- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density: $\sim 28 \text{ kg m}^{-2}$
 - HST (ULE) $\sim 180 \text{ kg m}^{-2}$
 - Keck (Zerodur) $\sim 2000 \text{ kg m}^{-2}$



A specially instrumented space simulation chamber at MSFC was used to optically test the primary mirror segments at 50 K (-225 C, -370 F)



All telescope optics are complete through cryo testing and are in spec in every respect



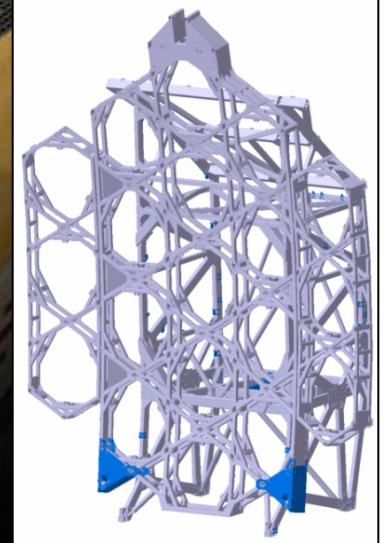
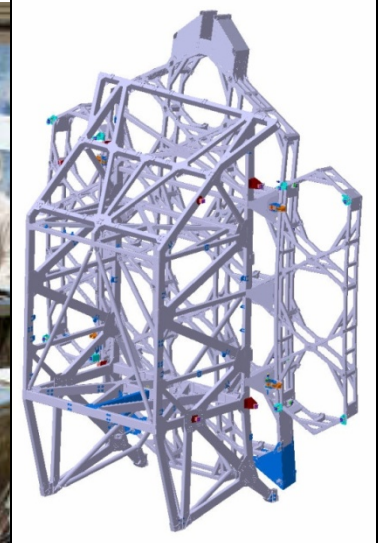
Buildup of telescope flight structure is nearing completion

Assembly consists of ~3,200 bonded composite piece parts

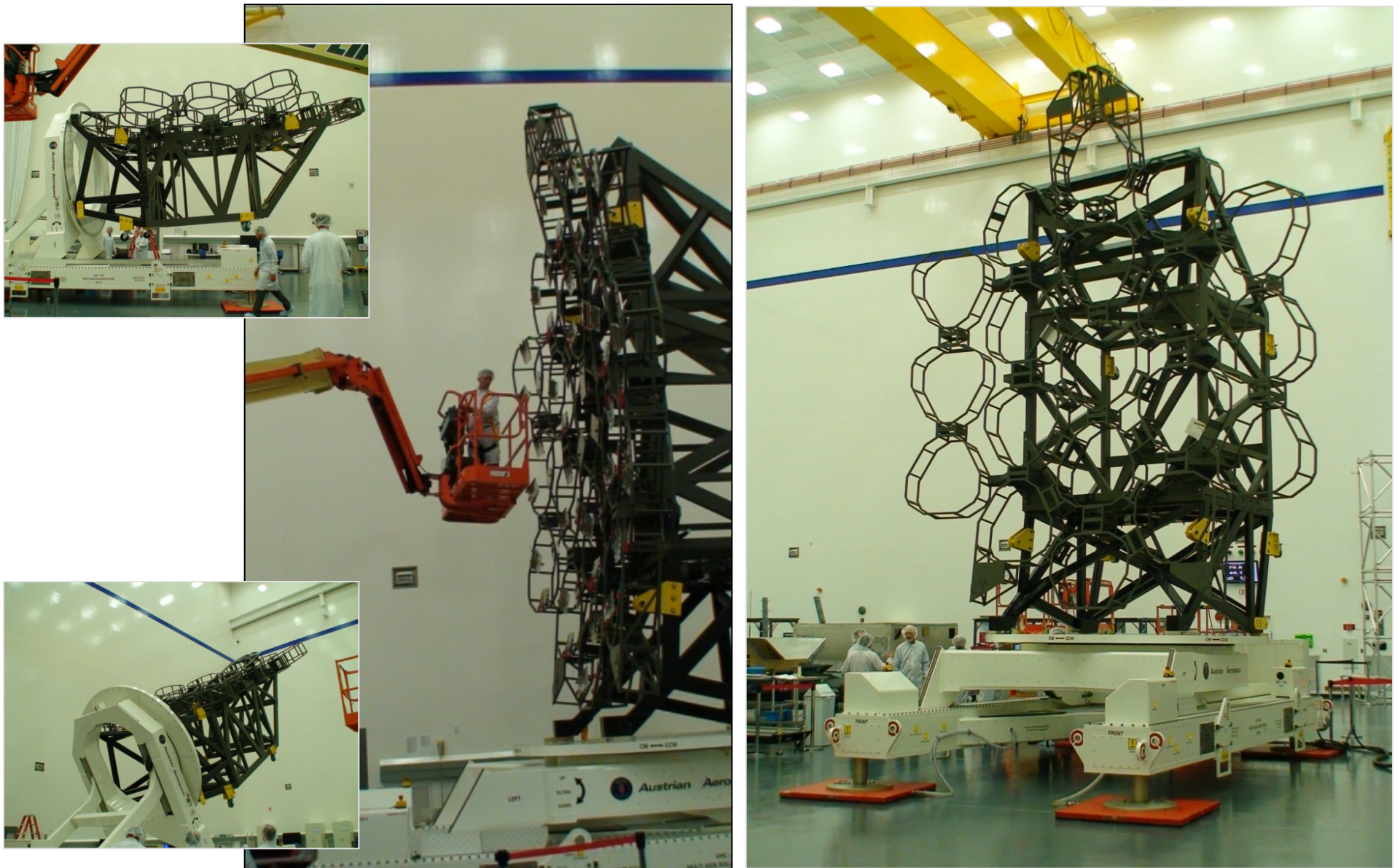
Center section of the flight backplane was completed during April 2012



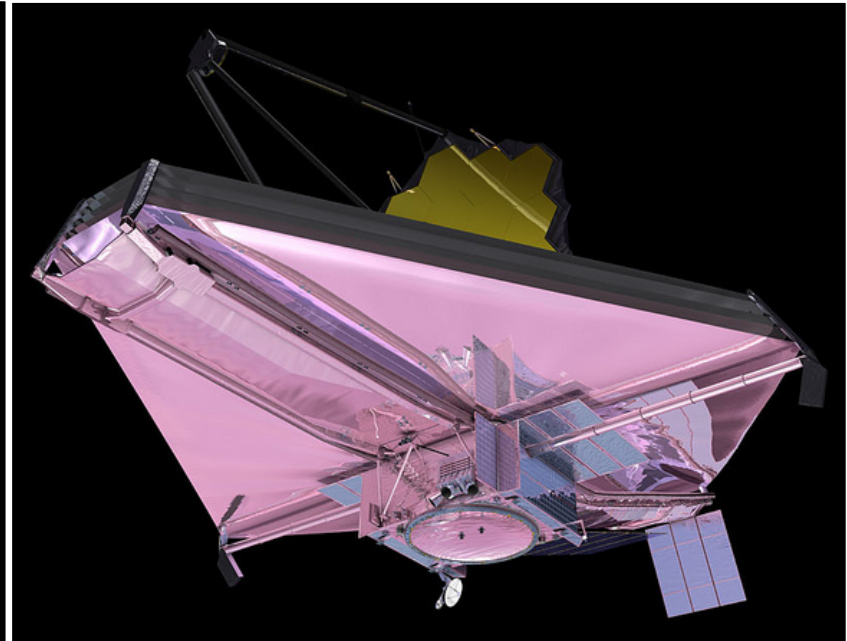
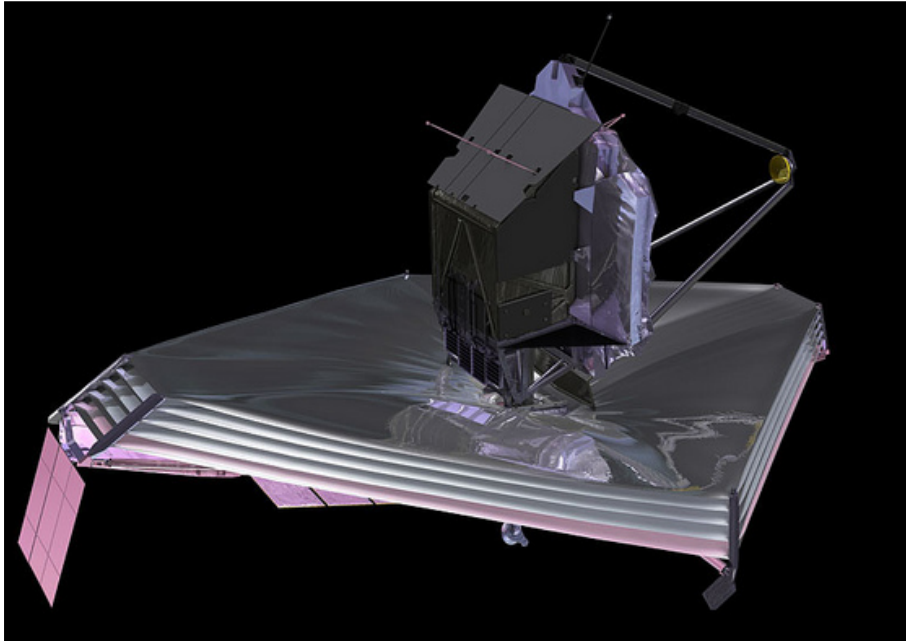
JWST OTE flight backplane center section at ATK facility



Full scale OTE mockup in handling test at NGAS



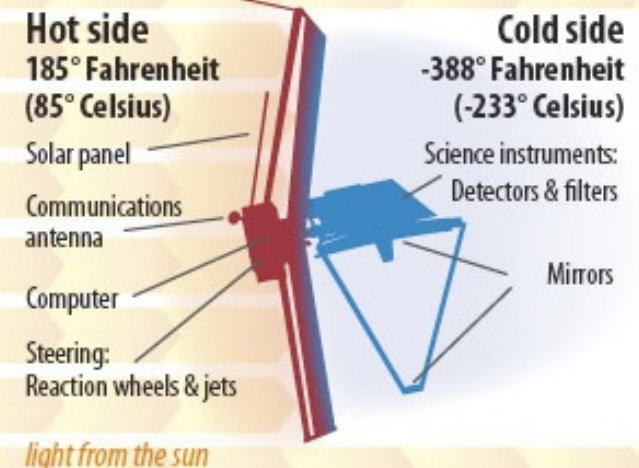
The JWST's 5 layer sunshield has an SPF of $\sim 10^6$



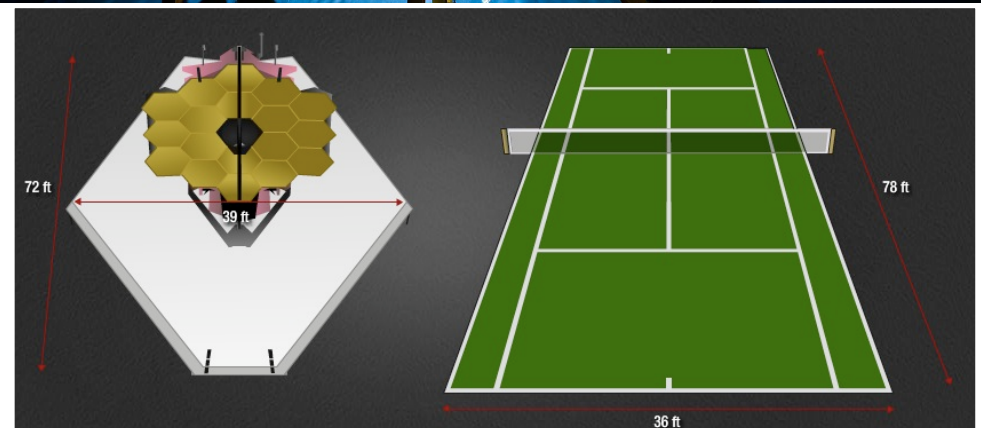
SUNSHIELD FACTS

- Measures 73 x 40 feet and has 5 layers
- Made of heat-resistant Kapton coated with silicon on sun side and aluminum on other surfaces
- Sun side reaches 358 K (85° C), dark side stays at 40 K (-233° C)
- Each of 5 layers consist of 50 pieces to form shape
- Seaming involves 7,000 inches of thermal welds
- Seam-to-seam accuracy ~ 0.05 inch with shape of (tennis court size) layers accurate to a few tenths of an inch

The Two Sides of the Webb Telescope



Sunshield thermal performance has been validated by a 1/3 scale test in a space simulation chamber



The JWST space vehicle consists of three elements

Optical Telescope Element (OTE)

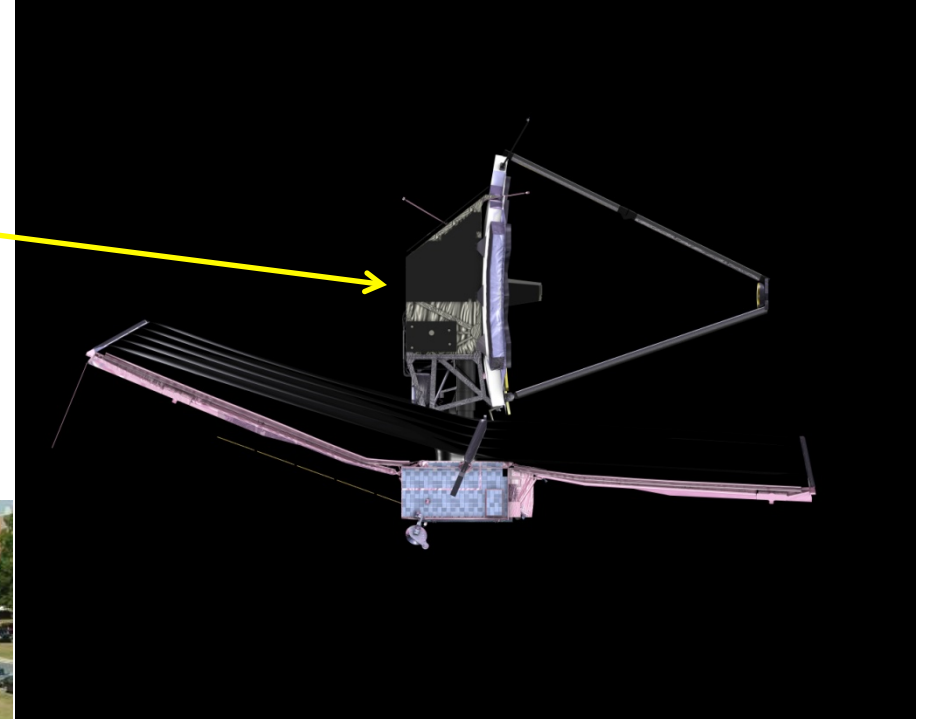
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)

Extracts physics information from star light

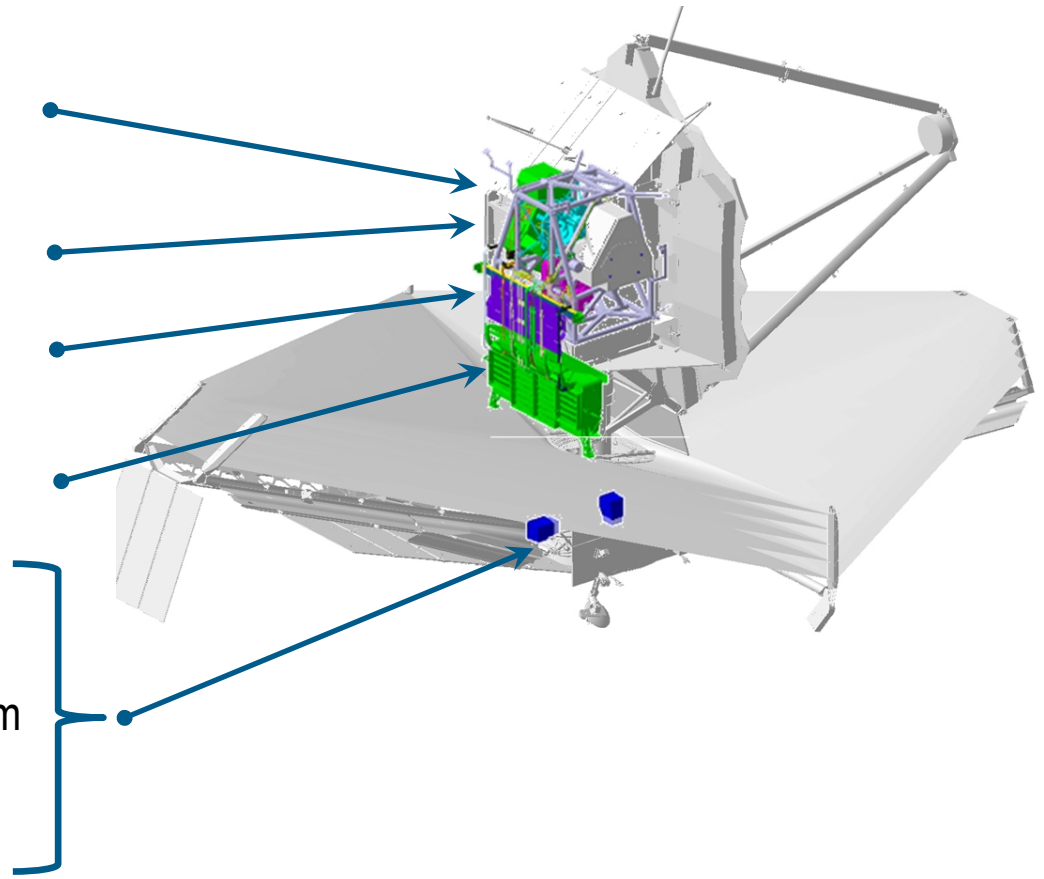
Spacecraft

Attitude control, telecom, power & other systems

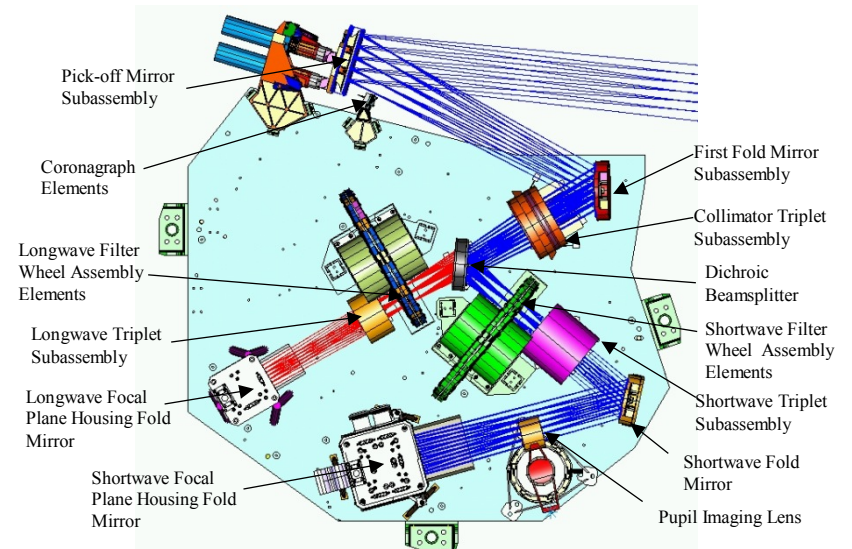
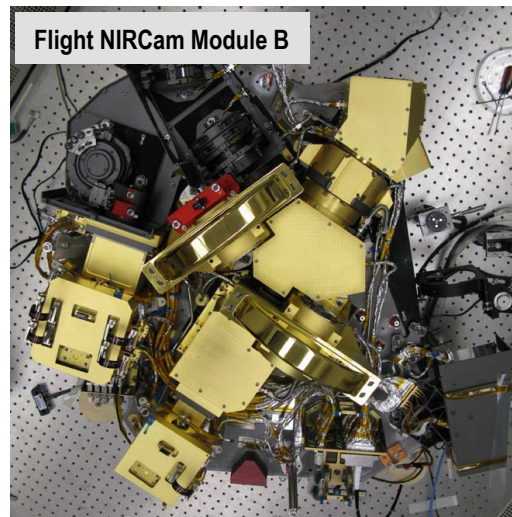
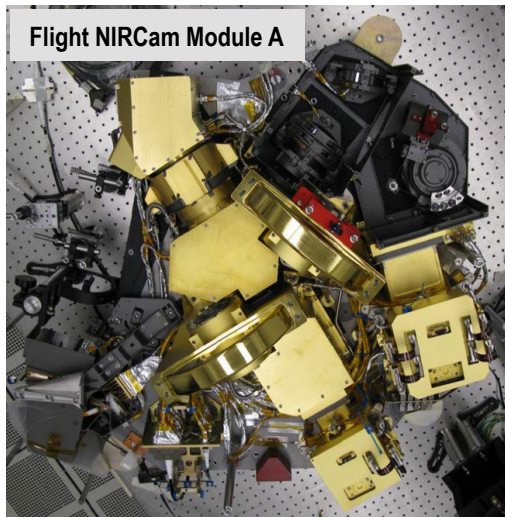


The Integrated Science Instrument Module (ISIM) is the science instrument payload of the JWST

- **ISIM is one of three elements that together make up the JWST space vehicle**
 - Approximately 1.4 metric tons, ~20% of JWST by mass
 - Completed its Critical Design Review during 2009 and is currently in integration and test
- **The ISIM system consists of:**
 - Four science instruments
 - Complete → - MIRI, FGS, NIRCam, NIRSpec
 - Nine instrument support systems:
 - Complete → - Optical metering structure system
 - Feb 2013 → - Electrical Harness System
 - Apr 2013 → - Harness Radiator System
 - Complete → - ISIM electronics compartment
 - Complete → - ISIM Remote Services Unit
 - Mar 2013 → - Cryogenic Thermal Control System
 - Complete → - Command and Data Handling System
 - Flight Software System
 - Operations Scripts System

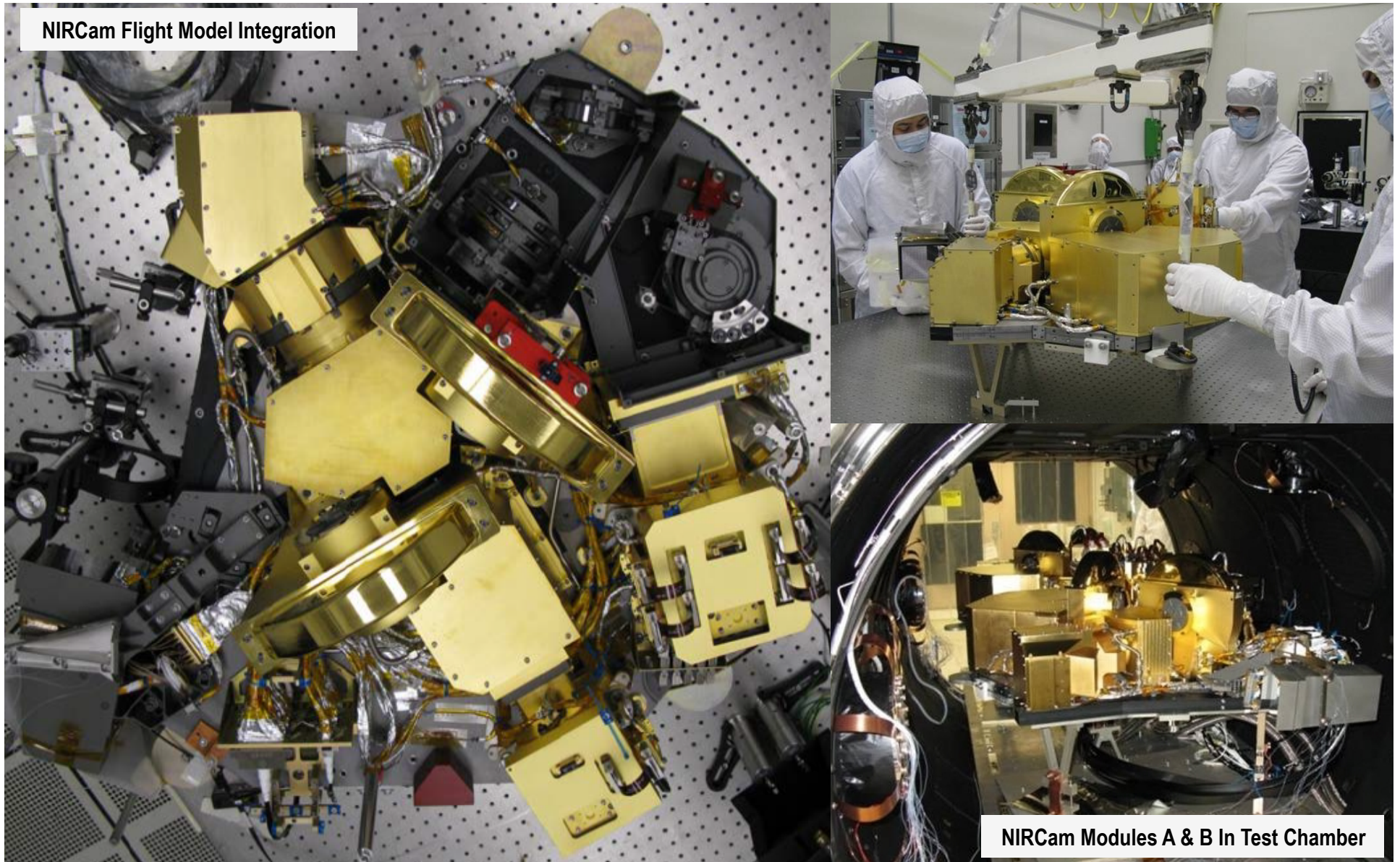


NIRCam will provide the deepest near-infrared images ever and will identify primeval galaxy targets for the NIRSpect

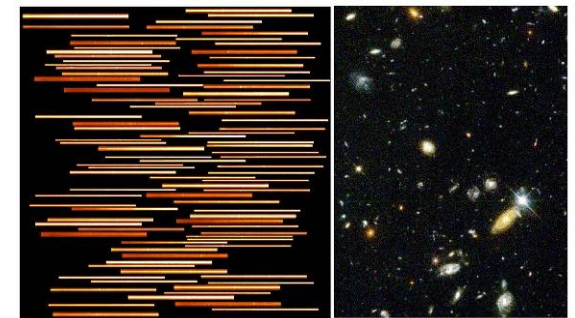
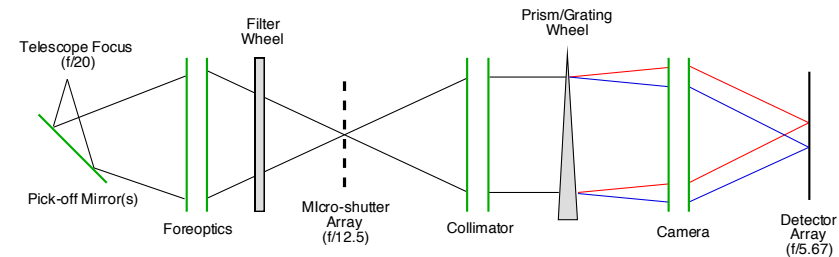
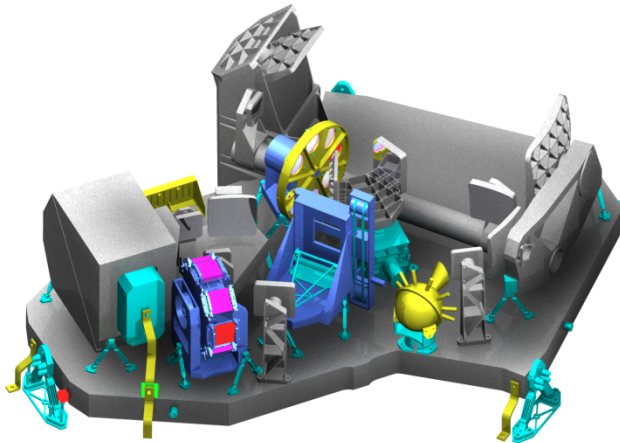


- Developed by the University of Arizona with Lockheed Martin ATC
 - Operating wavelength: 0.6 – 5.0 microns
 - Spectral resolution: 4, 10, 100 (filters + grism), coronagraph
 - Field of view: 2.2 x 4.4 arc minutes
 - Angular resolution (1 pixel): 32 mas < 2.3 microns, 65 mas > 2.4 microns
 - Detector type: HgCdTe, 2048 x 2048 pixel format, 10 detectors, 40 K passive cooling
 - Refractive optics, Beryllium structure
- Supports telescope wavefront sensing

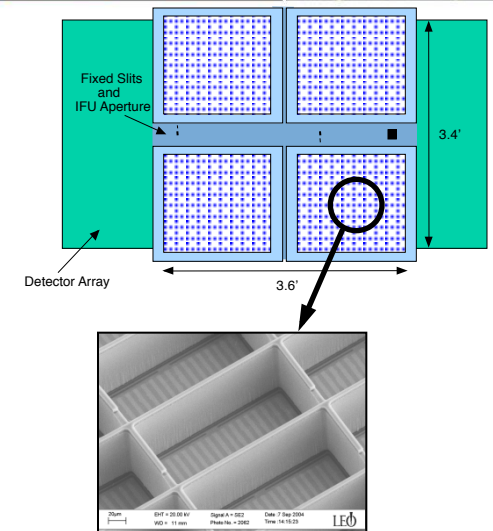
NIRCam will arrive at GSFC during early 2013



The NIRSpec will acquire near-infrared spectra of up to 100 objects in a single exposure

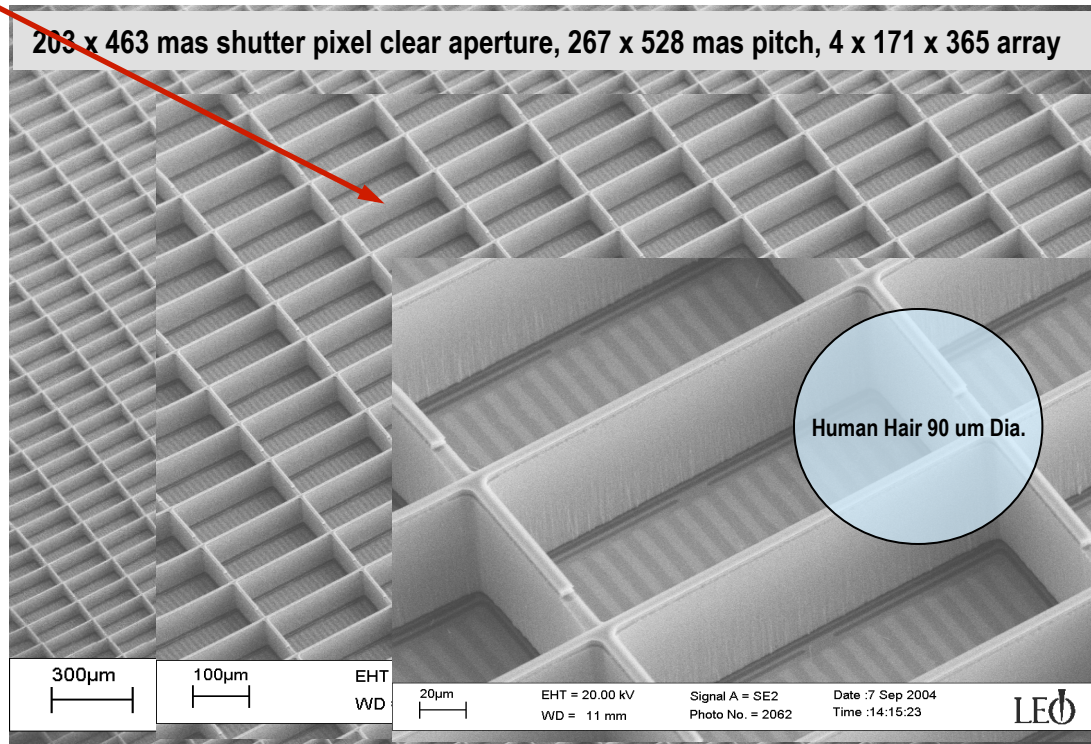
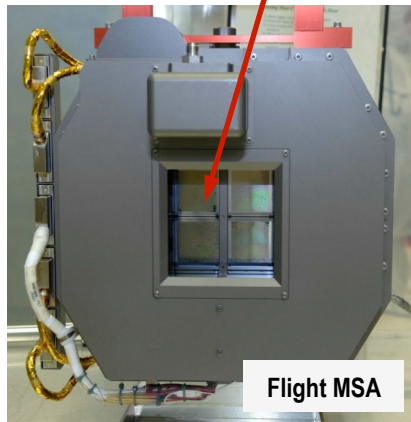
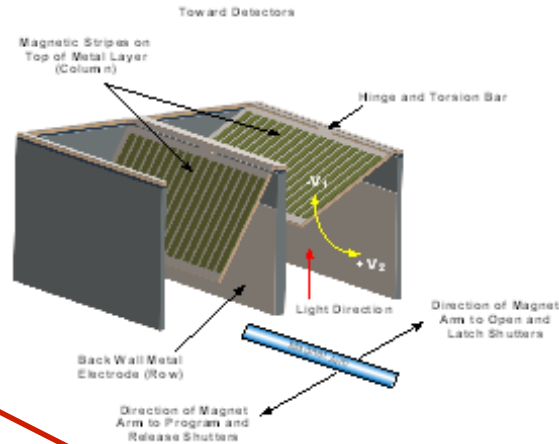
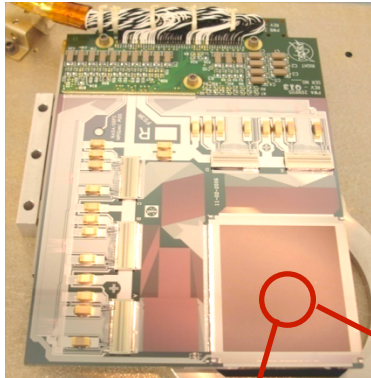


- Developed by the European Space Technology Center (ESTEC) with Astrium and Goddard Space Flight Center
 - Operating wavelength: 0.6 – 5.0 microns
 - Spectral resolution: 100, 1000, 3000
 - Field of view: 3.4 x 3.4 arc minutes
 - Aperture control:
 - Programmable micro-shutters, 250,000 pixels
 - Fixed long slits & transit spectroscopy aperture
 - Image slicer (IFU) 3x3 arc sec
 - Detector type: HgCdTe, 2048 x 2048 format, 2 detectors, 37 K passive cooling
 - Reflective optics, Silicon Carbide structure and optics



Aperture control: 250,000 programmable micro-shutters

System flight qualified and delivered to ESA June 2010



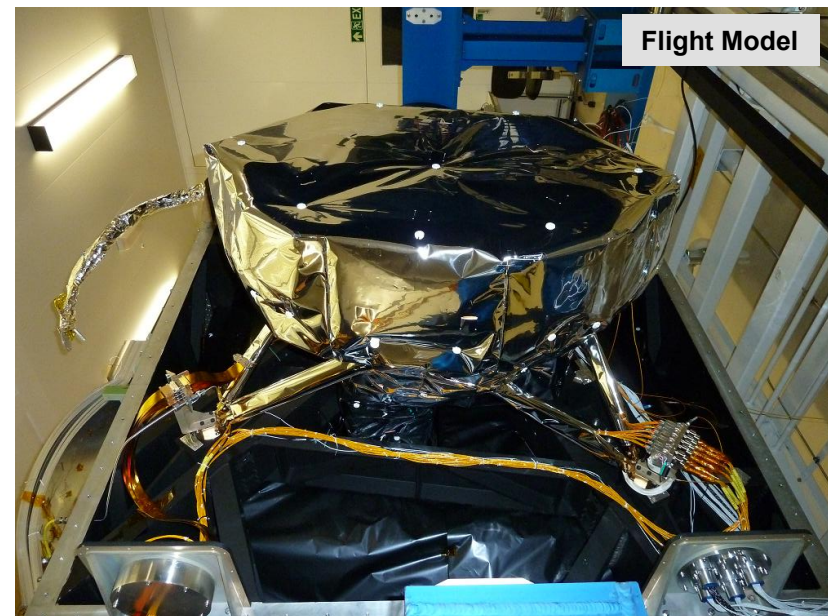
21 Feb 2013

Presentation to: University of KwaZulu-Natal, Durban South Africa: Distribution unlimited

NIRSpec delivery is expected during August 2013

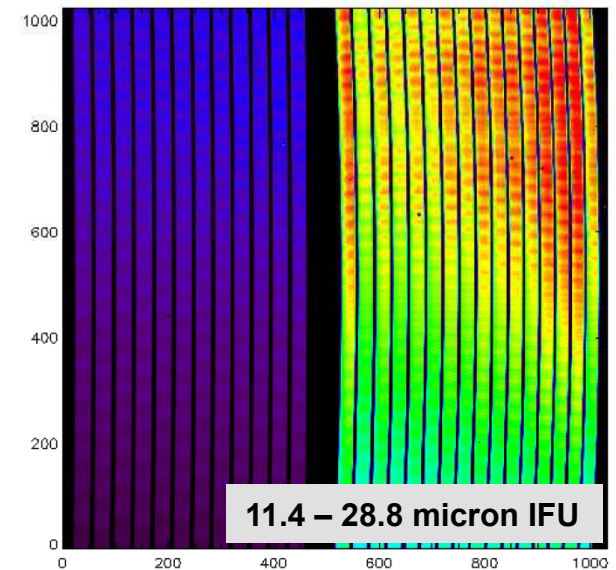
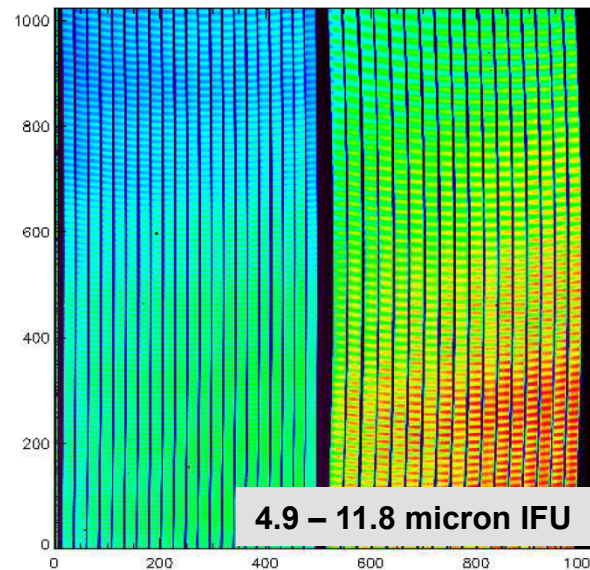
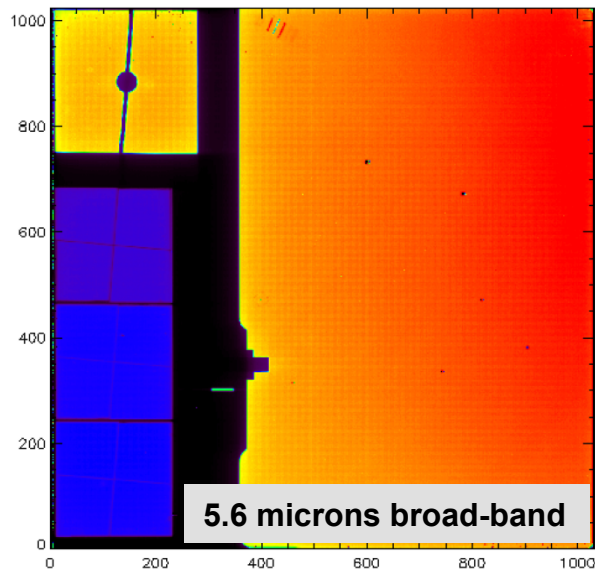
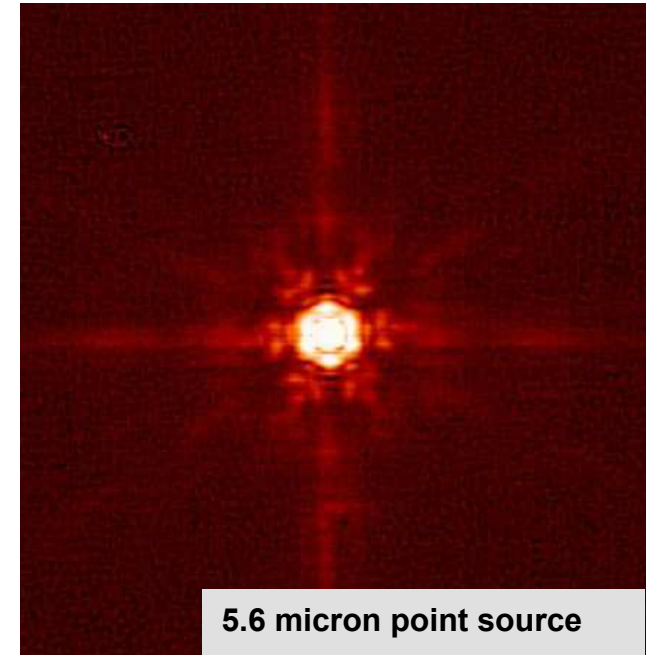
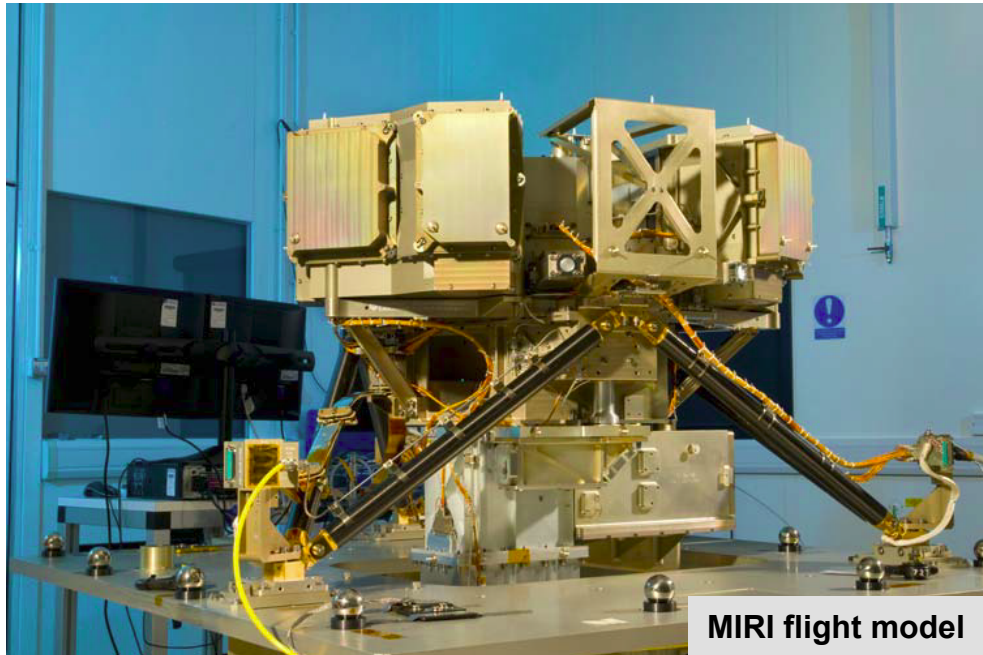


The MIRI instrument will characterize circumstellar debris disks, extra-solar planets, and the evolutionary state of high redshift galaxies

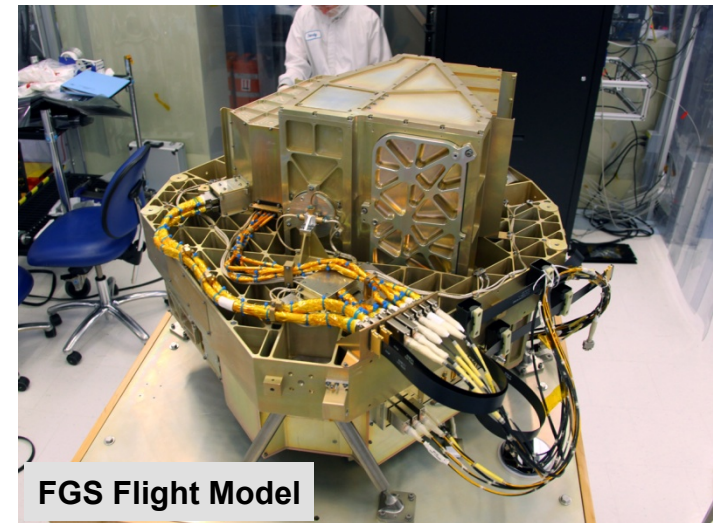
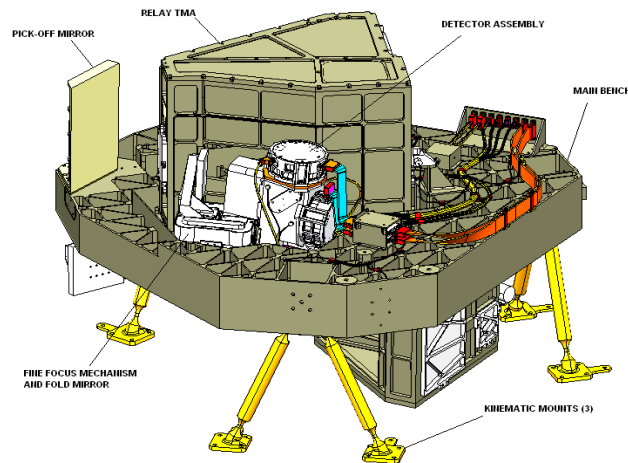


- Developed by a consortium of 10 European countries and NASA/JPL
 - Operating wavelength: 5 - 29 microns
 - Spectral resolution: 5, 100, 2000
 - Broad-band imagery: 1.9 x 1.4 arc minutes FOV
 - Coronagraphic imagery
 - Spectroscopy:
 - R100 long slit spectroscopy 5 x 0.2 arc sec
 - R2000 spectroscopy 3.5 x 3.5 and 7 x 7 arc sec FOV integral field units
 - Detector type: Si:As, 1024 x 1024 pixel format, 3 detectors, 7 K cryo-cooler
 - Reflective optics, Aluminum structure and optics

MIRI was delivered to ISIM I&T during May 2012



The FGS-Guider and -NIRISS provide telescope pointing control imagery & slitless spectroscopy for Ly- α galaxy surveys and extra-solar planet transits



- Developed by the Canadian Space Agency with ComDev
 - Broad-band guider (0.6 – 5 microns)
 - Field of view: 2.3 x 2.3 arc minutes
 - Science imagery:
 - Slitless spectroscopic imagery (grism)
 - R ~ 150, 0.8 – 2.25 microns optimized for Ly alpha galaxy surveys
 - R ~ 700, 0.7 – 2.5 microns optimized for exoplanet transit spectroscopy
 - Sparse aperture interferometric imaging (7 aperture NRM) 3.8, 4.3, and 4.8 microns
 - Angular resolution (1 pixel): 68 mas
 - Detector type: HgCdTe, 2048 x 2048 pixel format, 3 detectors
 - Reflective optics, Aluminum structure and optics

FGS was delivered to ISIM I&T during July 2012

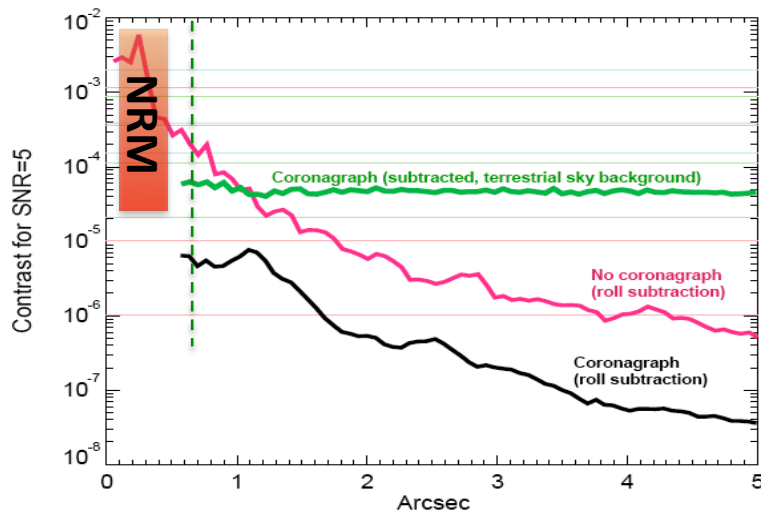


The NIRISS includes an Aperture Masking Interferometry (AMI) mode that enables moderate contrast imagery at an inner working angle of $\lambda/2D$

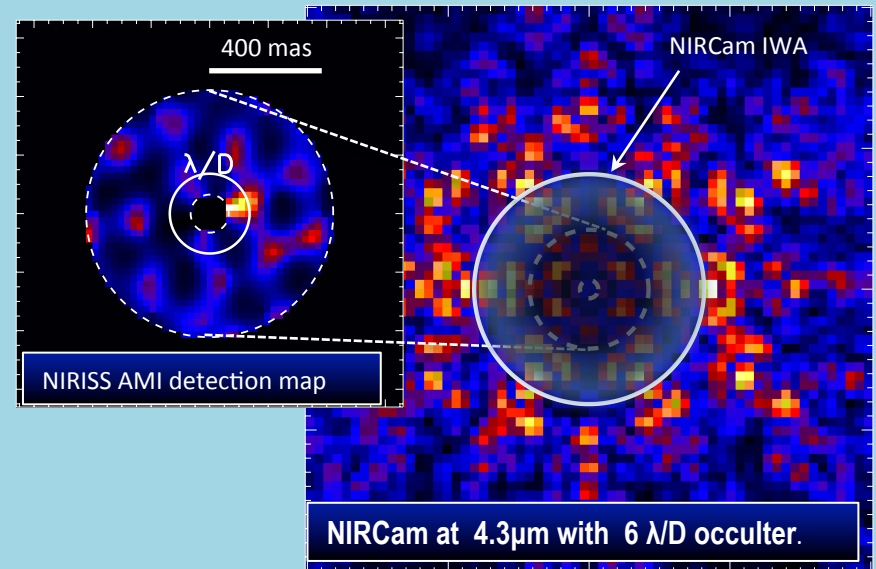
**Available in 3 broad-band filters:
3.8, 4.3, 4.8 μm over which NIRISS is
Nyquist sampled**

**Yields 10-12 magnitudes of point source
contrast over a 70-500 mas annulus**

**NIRCam coronagraphy limited to an inner
working angle of approximately 600 mas**



NIRISS & NIRCam IWA and contrast

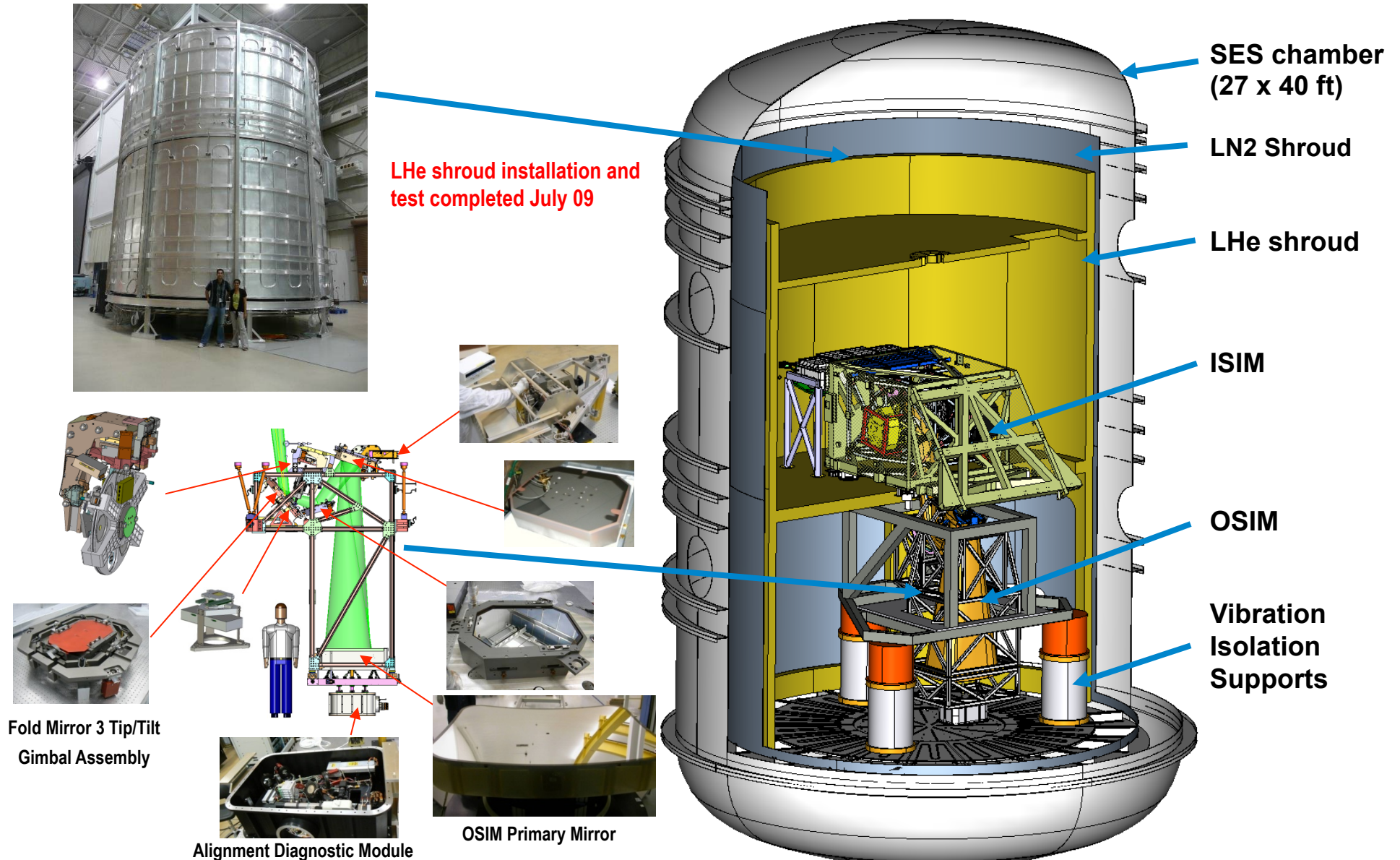


**Simulated companion above has contrast
of 10 mag at a separation of 130 mas**

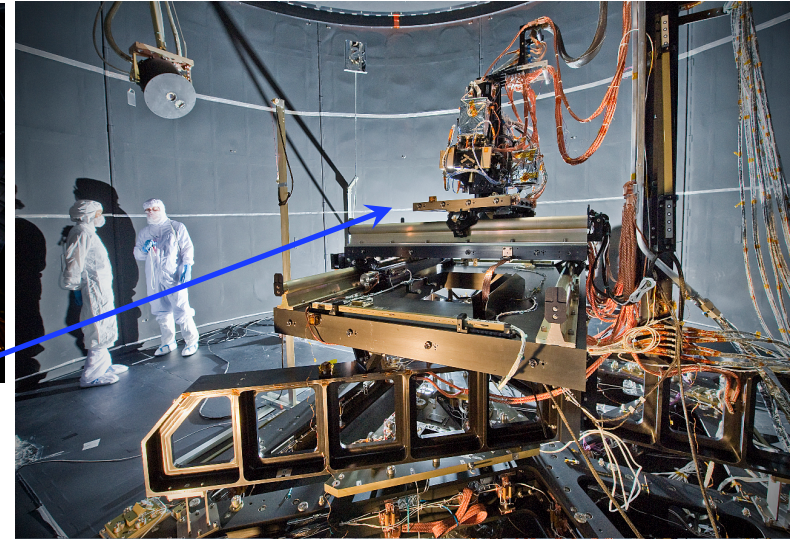
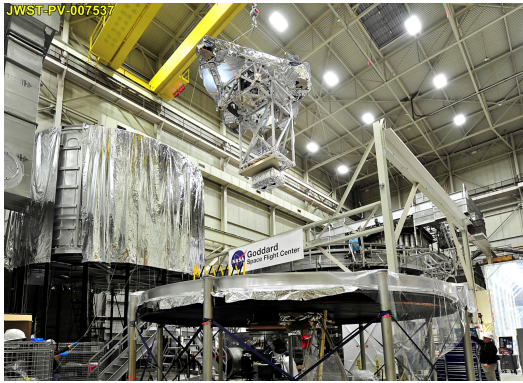
**Equivalent to a 1-2 M_{Jup} planet at ~ 1 AU
of a 50 Myr-old M0V dwarf at a distance
of 10 pc from the Sun.**

**Above simulation corresponds to
approximately 3 hours of observing time**

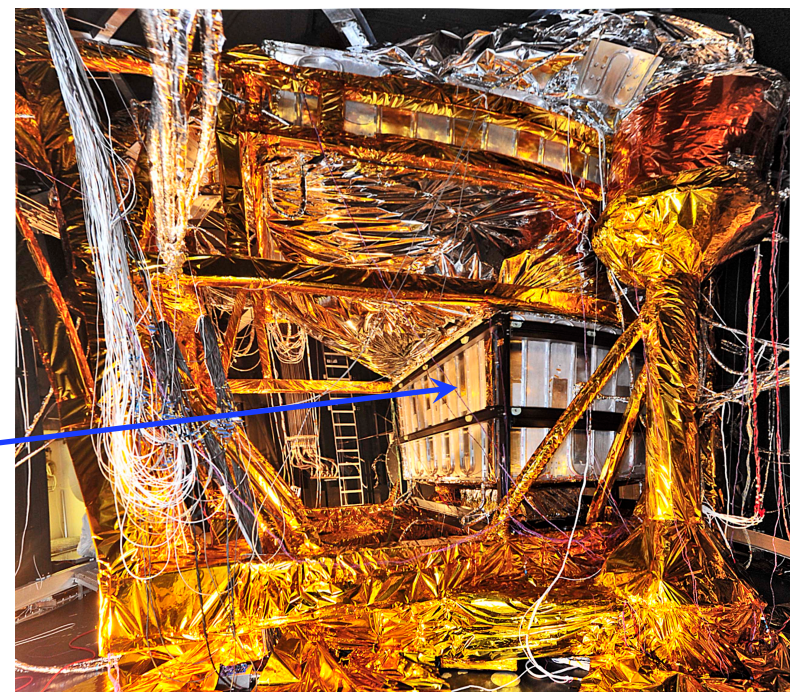
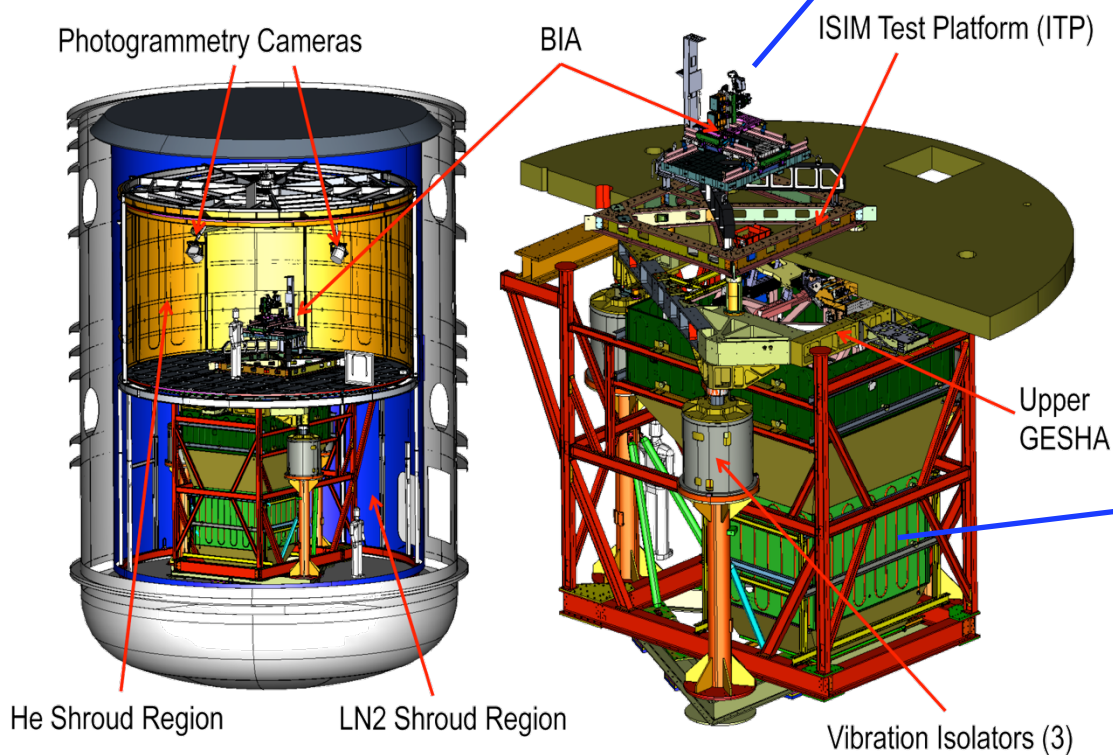
ISIM will be tested at ~35 K in the GSFC SES chamber using a cryogenic telescope simulator (OSIM)



OSIM-1 test configuration in SES chamber: June 2012



OSIM cryo-vac test configuration

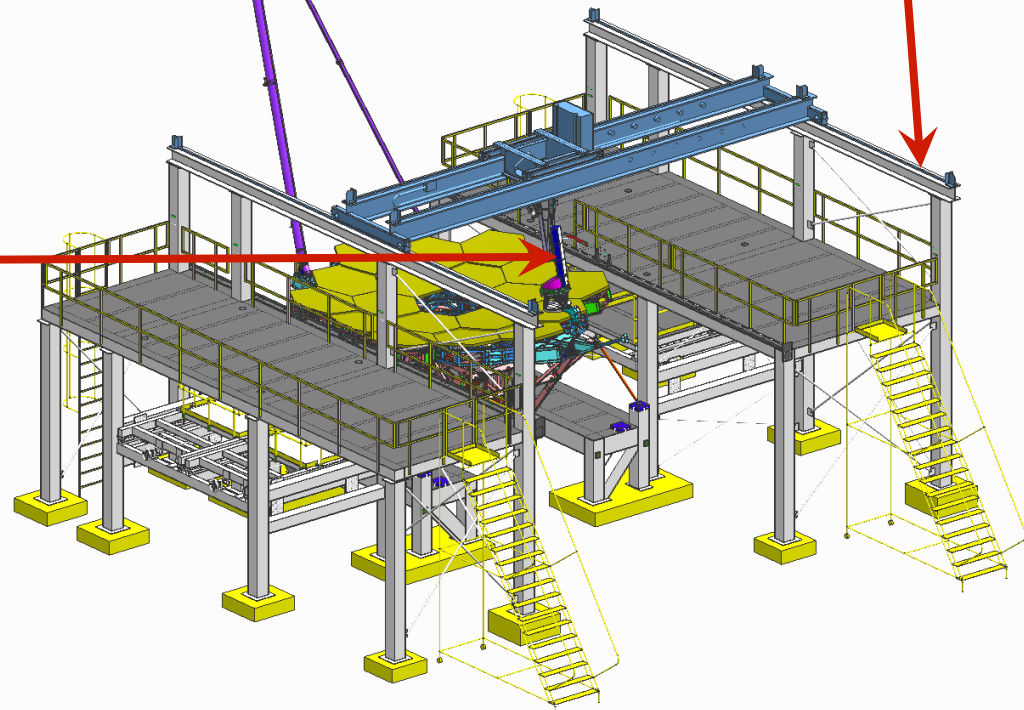


Optical Telescope Assembly Stand (OTAS) installation at GSFC is on schedule to support OTE integration

Used to manipulate primary mirror segments during integration with telescope backplane

Supports weight of entire optical telescope – a load of more than 3.7 metric tons.

OTAS itself weighs 139,000 pounds



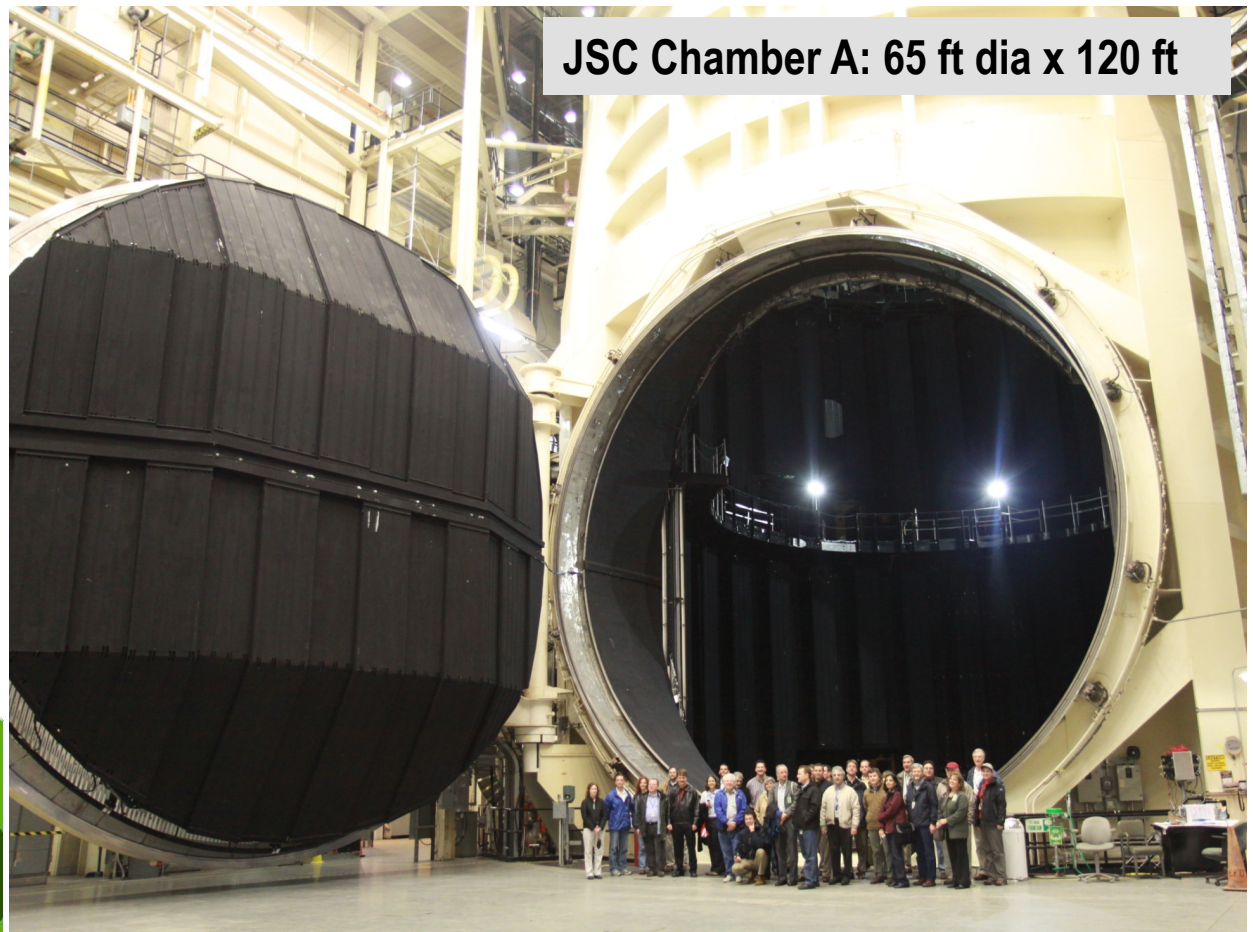
Then the OTE + ISIM will be tested in a larger space simulation chamber at Johnson Space Flight Center

Apollo era facility extensively refurbished for JWST

Largest deep cryogenic space simulation chamber in the world

Performance certification completed during Aug 2012

13 K and 10^{-8} Torr reached during test



Learn more at:

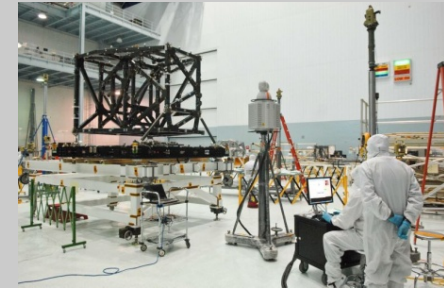
www.jwst.nasa.gov

http://webbtelescope.org/webb_telescope/progress_report/



Watch the JWST being built at:

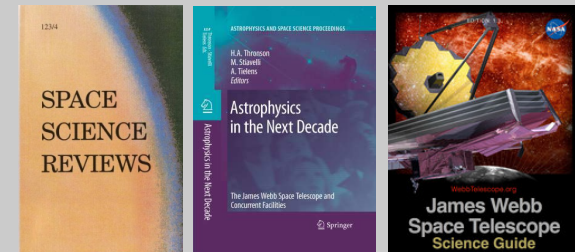
www.jwst.nasa.gov/webcam.html



Read about JWST science mission objectives at:

<http://www.jwst.nasa.gov/science.html>

<http://www.stsci.edu/jwst/science/whitepapers/>



Explore your science objectives with the JWST observing time estimator:

<http://jwstetc.stsci.edu/etc/>

Interact with the JWST Science Working Group:

<http://www.jwst.nasa.gov/workinggroup.html>

The End (of this presentation)

But

with JWST, we will see the beginning of *everything*

The first galaxies
The origins of galactic structure
The birth of stars
The creation of planets
and more

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Supplemental Slides

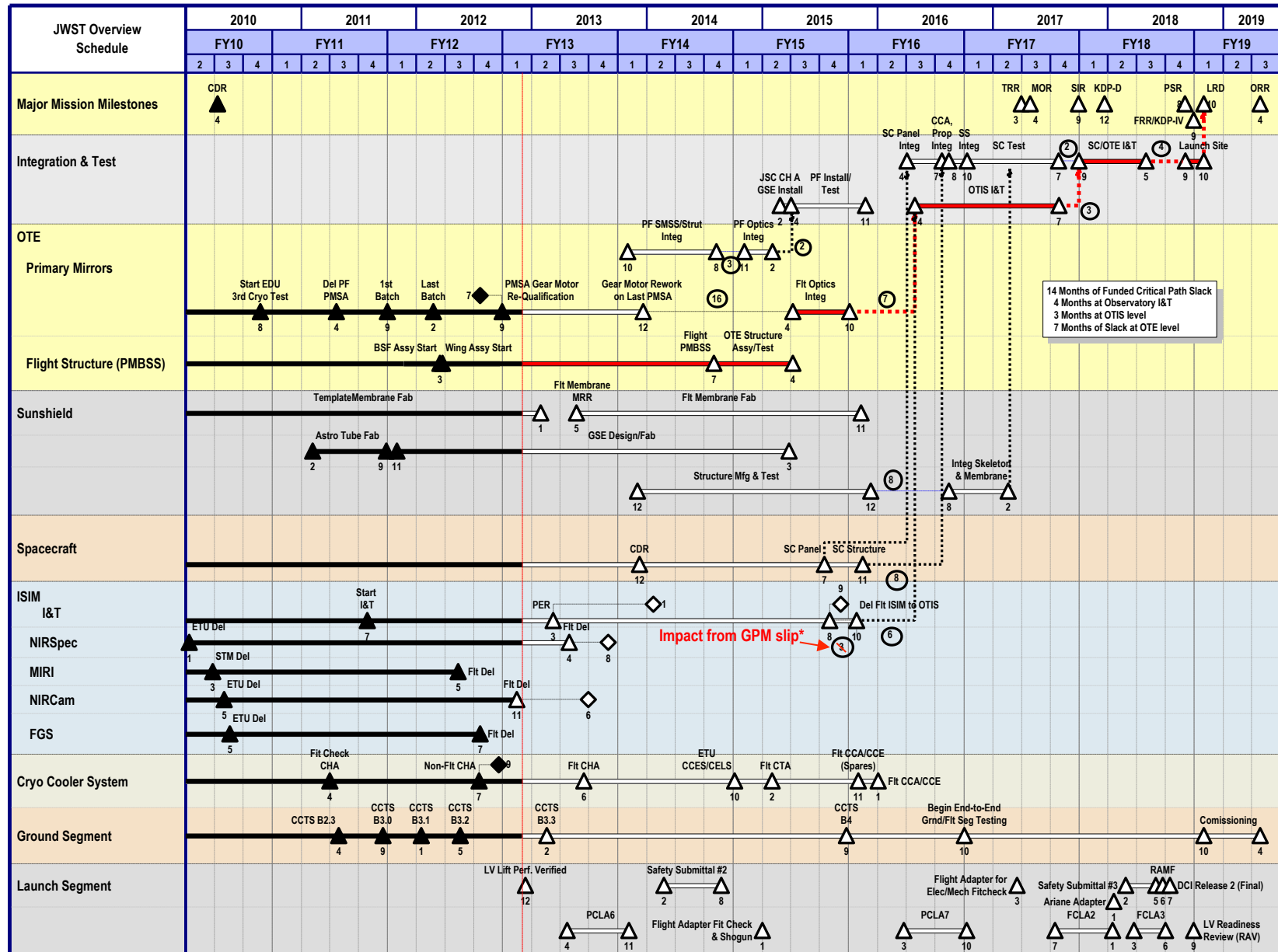
WHO WAS JAMES WEBB?



JAMES WEBB (1906 – 1992)

- **SECOND ADMINISTRATOR OF NASA (1961 – 1968)**
- **OVERSAW:**
 - **FIRST MANNED SPACEFLIGHT PROGRAM (MERCURY)**
 - **SECOND MANNED SPACEFLIGHT PROGRAM (GEMINI)**
 - **MARINER, PIONEER PLANETARY EXPLORATION PROGRAMS**
 - **APOLLO PROGRAM**

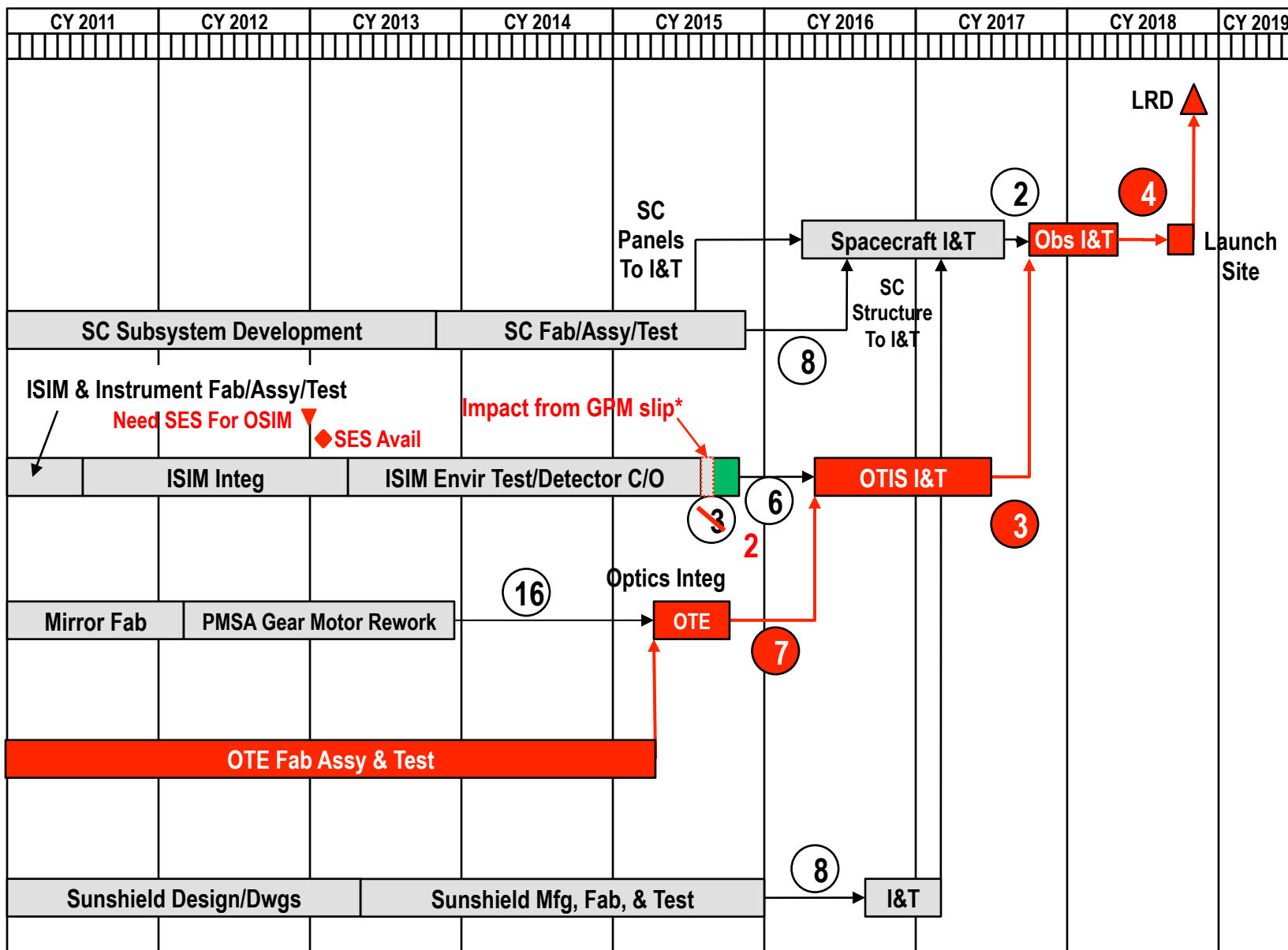
JWST Master Schedule



Baseline 5/24/12

Rev K

JWST Master Schedule

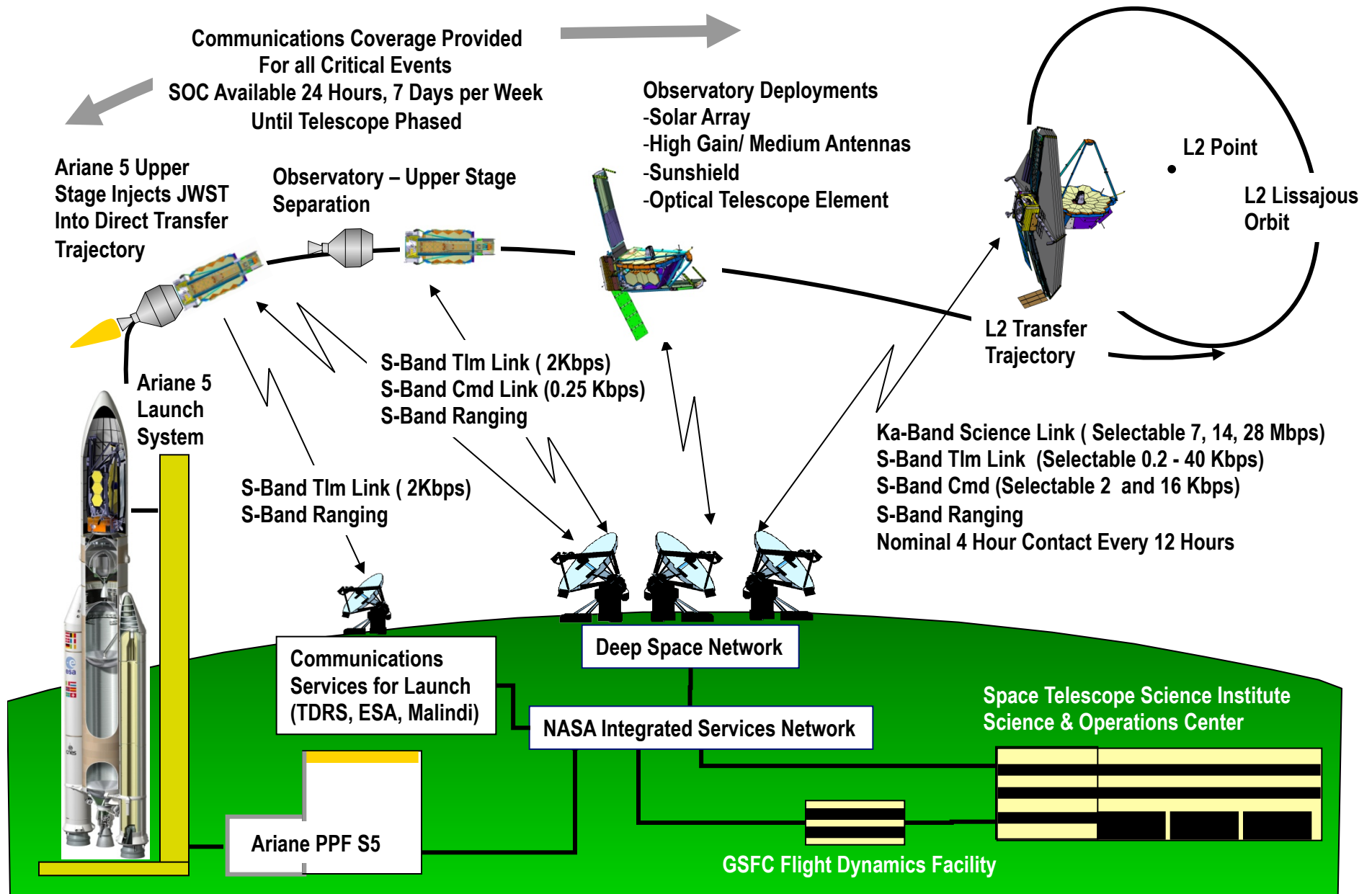


Space Telescope Transporter for Air, Road & Sea (STTARS)

STTARS Is Completed



JWST System Architecture Summary



Astrophysics Missions timeline

Last updated: October 1, 2012

